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REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS.

ON THE SIMONDS UNIVERSAL METAL-ROLLING MACHINE.

HALL OF THE FRANKLIN INSTITUTE.

PHILADELPHIA, September 5, 1888.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred for examination

GEORGE F. SIMONDS'S ROLLING MACHINE,

Report: That they have carefully examined the same and considered his request for the award of the Elliott Cresson Medal of the FRANKLIN INSTITUTE, and find as follows:

The invention, in its general scope, is included in the letters-patent of the United States, numbered 319,755, and dated June 9, 1885, granted to George F. Simonds, of Fitchburg, Mass., for "Method of Forging Metal Bars," submitted

to your committee by the inventor, with his application. There are thirteen other letters-patent granted to the same inventor for the machines and instruments for performing this and collateral work, and for the products of such machines numbered, dated and entitled, as follows:

Four, dated June 9, 1885, viz:

No. 319,752. Machines for forging car axles and other metal articles.

No. 319,753 for machine for making car wheels.

No. 319,754 for dies for forging metal articles circular in cross-section.

No. 319,756 for die for spherical articles.

Three, dated September 7, 1886, viz:

No. 348,788 for shell and method of making the same.

No. 348,789 for armor piercing shell.

No. 348,790 for dies for making rolled forgings.

Three, dated November 9, 1886, viz:

No. 352,365 for die for making rolled forgings.

No. 352,366 for roller swaging die.

No. 352,367 for making metal rolling dies.

Three, dated March 1, 1887, viz:

No. 358,627 for rolled conical projectiles.

No. 358,628 for die for making rolled forgings.

No. 358,629 for die for making rolled forgings.

The object of the invention is the economical and accurate production from ductile or malleable metal articles of circular, or approximately circular form, other than simple cylinders.

The means resorted to for attaining such results concisely stated, consist in swaging dies moving in opposite directions with surfaces which approach each other and first roll the ductile metal to form and afterward produce, by continued rolling, a finished surface.

The important feature distinguishing this invention from other devices having a like object in view, is the extension or drawing of the metal of a rod in the direction of its axis, attended with a reduction of diameter in whole or in part, in contradistinction from attempting to shorten or upset the metal, and thicken portions of the metal to a greater diam-

eter than that of the rod, and with this further feature the avoidance of any attempt to finish the surface until the metal has been shaped in the form required for the completed article.

The machine exhibited to your committee, in operation at the works of William Sellers & Co., incorporated, No. 1600 Hamilton Street, in this city, consists of two vertically reciprocating sliding tables, moving in guides simultaneously at equal velocities in opposite directions by racks and pinions, propelled by a train of toothed gearing operated by pulleys turning in reverse directions, and alternately engaged therewith by a coupling or clutch, the coupling being operated by a shifter, participating in the motion of the gearing propelling one of the slides; one of the guides with its sliding table is adjustable, as to distance from the other, so as to make required changes in the diameter of the work produced.

The dies are fixed to the inner sides of the slides and are of such form, that as one descends and the other ascends, the space between them diminishes.

A heated bar of metal being placed between them, is rolled thereby whilst its axis retains the same position.

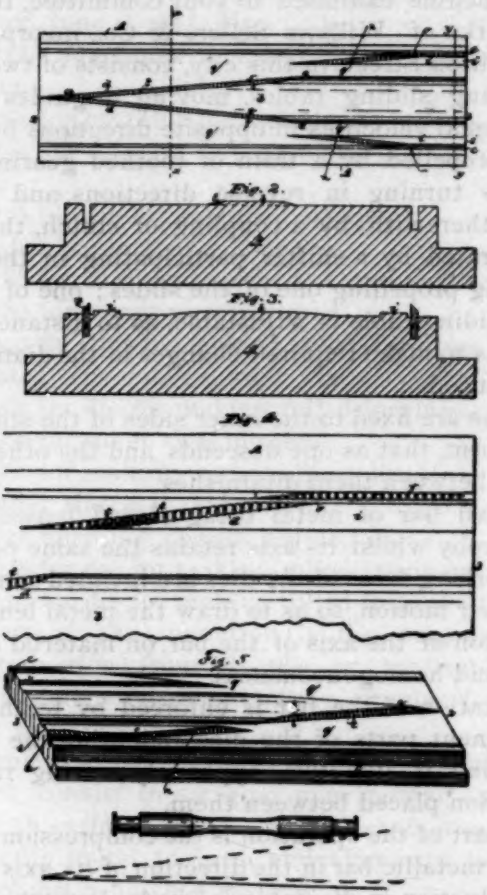
The working faces of the dies are inclined as to the direction of their motion, so as to draw the metal lengthwise, in the direction of the axis of the bar, on material of requisite strength and homogeneousness.

The rotation of the bar is enforced by teeth formed in the prominent parts of the dies, indenting the metal and thus turning it, like two oppositely-moving racks would turn a pinion placed between them.

In no part of the operation is the compression or shortening of the metallic bar in the direction of its axis attempted.

The reduction in diameter is gradual, so that, in material of a reasonable degree of strength and homogeneousness, there is never a severance of metal at the centre by the metal being flattened and moving in opposite directions at the centre, producing what is known as piping or a hollow centre; but instead an extension in the direction of the axis. This effect is produced by the gradual inclination of the

dies toward each other, attended with a relatively very rapid divergence of the prominences or ridges and intervening cavities of the dies. This configuration of the dies proceeds to the point where all parts of the article are



Simonds's U. S. Patent No. 319,754.

reduced to the proper diameter. In the rest of its length the ridges or working surfaces of the dies are parallel and finish or smooth the surface of the article.

A good illustration of the shape of the dies appears in *Figs. 1, 2, 3* and *5* of Simonds's patent, No. 319,754, showing

the dies, and below a car axle produced by their operation, which figures are here inserted and now explained in detail.

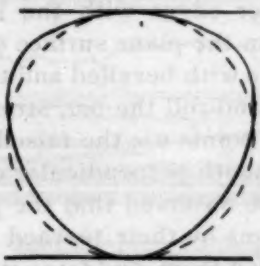
The foremost portion of the dies are marked *2*, being at the left end of *Fig. 1*, and the right of *Fig. 6*. The portions of the dies marked *q q* are sufficiently low or thin to permit the heated rod to pass freely between them, the weight of the rod being supported by a rest outside of the path of the dies. An inclined part rises from the point marked *2* to the point marked *a*, and gradually widens from the point *2* to the points *c*, being parallel or nearly so with its line of motion from the point *a* onward; the edges of the triangular part *a, c, e*, being bevelled and having teeth formed in them which indent the metal and ensure rotation of the bar. It will be seen thus that the dies engage the bar at the centre, leaving the ends free, and gradually reduce its diameter from the centre toward the ends. This action continues until the reduction of diameter of the central parts of the axle is effected, after which this part simply rolls between the parallel parts, extending from the points *e e* to the end of the die marked *3*.

Upon the completion of the reduction of diameter of the central parts, two raised portions of the die, marked *i i*, parallel on the inner edges with the line of motion and gradually rising from the plane surface *q q*, and widening to the points marked *o o* with bevelled and toothed outer edges, marked *n n*, engage and roll the bar, stretching it in length; after reaching the points *o o*, the raised portions *i i* extend with parallel and smooth perpendicular edges to the end *3* of the die. It will be observed that the parts *i i* throughout their tapering portions by their toothed and bevelled edges roll the metal between them, and force it outwardly, leaving the form of the parts between the bevelled edges unchanged, thus forming the reductions in diameter required for the journals of the axles. After the parts marked *o o* of the die reach the bar, the extension of metal ceases, and a smooth rolling of surfaces proceeds. At the same time that the parts *o o* of the dies pass the rod, which by this time has become an axle, two raised portions of the die marked *c c*, rising gradually above the surface *q q* to the height of the centre

of the axle, and having smooth perpendicular inner sides, and bevelled and toothed outer sides, engage the metal and roll circumferential grooves in it, which increase gradually in depth, until the superfluous metal is severed from the ends of the then completed axle.

In order to afford a clearer conception of the direction of inclination of the working surfaces of the dies to their line of motion, and thus indicate the relative slowness of the diametral reduction to the lengthwise extension of the forging, three lines are drawn beneath the figure of the axle. The horizontal full line indicates the line of motion of one of the dies; the dotted oblique line nearest to it, the rate of diametral reduction, and the upper dotted line the rate of lengthening or drawing out of the forging.

It is found experimentally that a rod having a form of a triangle, with convex curved sides and corners, containing a greater mass of material than a cylinder of the same diameter, will roll between two parallel surfaces moving in opposite directions. If these surfaces in the dies of this machine are so shaped as to approach each other more rapidly than the metal is disposed of by drawing out lengthwise, such a form of section results and the metal in the

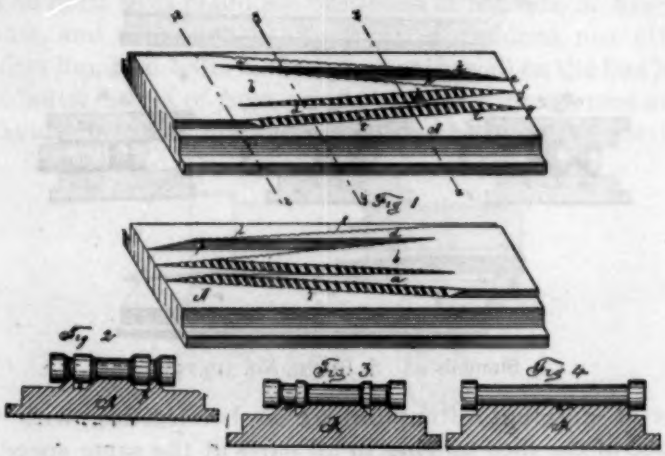


centre of such form is not solid but hollow or piped. This is illustrated in the figure showing the relative size and forms of the circle and curvilineal triangle, the proportions of which are exaggerated, to more fully show the feature involved.

As above described and shown, the extension in length and reduction in diameter commenced at one point in the centre of length and extended toward the ends, but the

invention is not limited to this mode, as shown in the next drawing taken from Simonds's U. S. Patent, No. 319,755.

The extension commences at three points in the length of the bar by three working faces marked *a*, *c* and *d*, on the dies commencing at points marked *e*, *f* and *g*, the inside



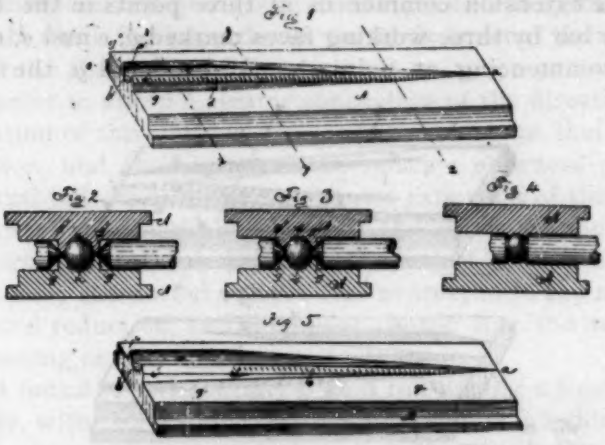
Simonds's U. S. Patent No. 319,755.

lines of the outer working faces *a* and *d* diverging from the points *e* and *g*, so as not to impede the extension of metal by the central working face *b*. As compared with the dies first described, the operation of these outer additional working faces is simply cumulative, and the advantage derived from them is that the work is accomplished more quickly by shorter dies in a machine of less stroke than would otherwise be required.

The other patents relate to the application of this system to the production of special forms, such as solid spheres and hollow shells for projectiles, and to details. A patent for rolling car wheels is also submitted, but is not in the opinion of your committee properly within the scope of their inquiry.

That for spheres, Simonds's U. S. Patent, No. 319,756, has transverse cavities, extending partially across the working faces of the die, passing over parts of the forging already shaped, which avoid part of the friction incident to dies, when the working faces are continuous, and corre-

spondingly avoid torsional strain upon parts of the forging which, if otherwise, would result from enforced contact of



Simonds's U. S. Patent, No. 319,756.

parts of different circumference and velocities, with the surface of the dies moving in all parts at the same speed.

The earliest form of the Simonds rolling forging machine is here shown, taken from Simonds's U. S. Patent, No. 319,752. (*See inset plate.*)

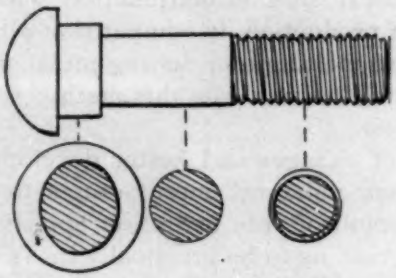
Whilst it differs in form from that now in use, it embodies the method or system of operation above explained, and upon which the value of the invention rests. The slides, with the dies moving simultaneously in opposite directions, are present with the inclination of surfaces of the dies, and the divergence and bevelling of the drawing surfaces and, with a machine so constructed, the feasibility of the invention was tested and demonstrated.

So far as described, the invention appears only as applied to the production of smooth-surfaced articles of circular cross-section.

As demonstrated by the machine in operation, above referred to, the invention is also successfully applied to the making of articles having prismatic and other forms of cross-sections in parts, and also with screw threads, such as bolts for railway splice joints.

These bolts have, as shown in the drawing here inserted, hemispherical heads, an elliptic or flattened part next to the head, a cylindric shaft terminating in a screw-threaded portion having a blunt conical point. The forms of cross-sections are represented below at the several points in the length.

The bolts thus made are produced at the rate of five per minute, and with such accuracy that a standard nut fitting the first hundred bolts made, fits equally well on the last hundred bolts, in lots of from 5,000 to 10,000 without renewing, changing or in any manner adjusting the dies; the portions



of the forgings, which depart from a circular form of cross-section, are made by correspondingly wave-shaped elevations and depressions in the working faces of the dies, the rotation of the bar being enforced by teeth in the working faces engaging either the surfaces of the forging or of a part of the bar contiguous thereto.

A card of specimens of the work produced demonstrates the extensive applicability of the invention, and consequent almost incalculable value for work of which many duplicates are required. (*See frontispiece.*)

The work, as it leaves the machine, approaches lathe-turned work in accuracy of form and dimensions. The effect of this method of treatment of metal is to improve its qualities of tenacity. The manner in which the metal is displaced from the parallel or cylindric forms, in which it enters the machine, to the tapering or shouldered forms which it assumes in the finished product, is shown by sections of the articles which have been polished and etched with acid, showing by the streaks and veins the direction of the flow

of metal under pressure. The lines of the veins show that the fibres are unbroken and in no case bent back upon each other.

For purposes of comparison an iron bolt of the same pattern has been similarly treated and placed with the others, the direction of fibres in upset iron specimen plainly appearing.

The Simonds specimens are uniformly solid in all parts.

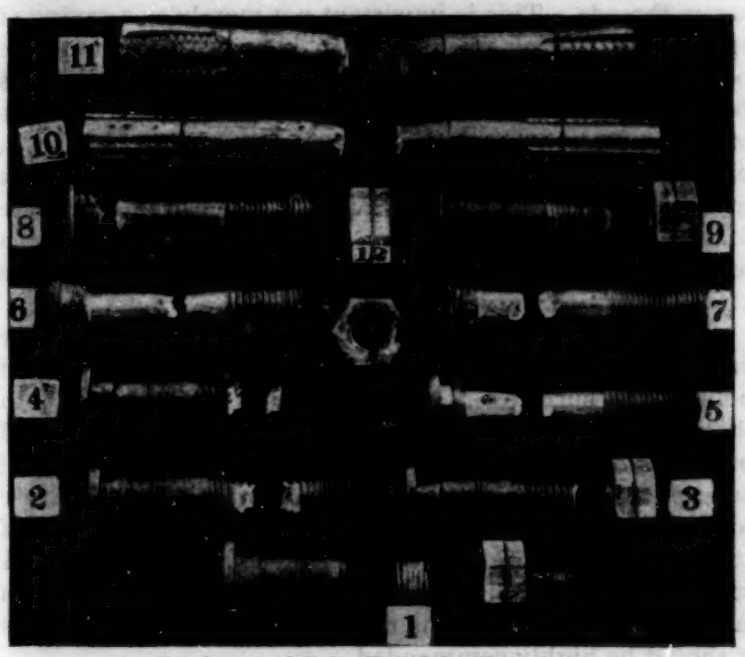
It is evident that the superior strength and uniform density in all parts as compared with castings either of steel or iron, considered in conjunction with the celerity and low cost of production, in competition with the expense of moulding and melting and casting metal, must cause the roll forged projectiles made by this method to supersede all others yet known.

The extent of changes and better developments in this and of dependent collateral manufactures, to be reasonably expected as a result of this invention, appears to your committee as so great as to be practically incalculable. Tests of the tenacity and ductility of the bars of material made by the Fairbanks testing machine, at Seventh and Arch Streets, in this city, show that the bolts produced by the machine retain the ductility and strength of the bar before it is subjected to the operation of the machine, as will appear in the following report of tests made in the presence of and observed and recorded by your sub-committee, on the 18th day of August, 1888.

Eleven specimens were tested, and the results recorded for the purpose of comparison are here tabulated, together with sketches describing the several specimens with these tests of the products of the Simonds machine. There were also made, for purposes of comparison, tests of similar standard bolts, made by Messrs. Hoopes & Townsend, of this city, and recognized by all of the principal railway companies as the best in use. The tests are numbered 1 to 11, and show the bolts produced by this process to be of superior quality and strength, as will appear upon inspection of the tabulated report of the test, shown upon the opposite page.

The parts of the specimens tested are fastened to a card, and numbered to correspond with the order in which the tests were made. Our examination of the fractured parts shows that the tenacity of the material is unimpaired by the Simonds method of working.

A comparison of the tests of bolts made with those of the best manufacture heretofore known, strongly commends those of the Simonds manufacture. It is noticable that the iron nuts used in making the tests appear to be equal in



Specimens of Bolts Tested by Committee.

strength to the steel bolts, the strongest steel bolt tearing the thread out in the first test, and in the second, fourth, fifth, sixth and seventh breaking the bolts.

There can be no doubt but that a reduction in diameter occurs at the instant, or in the act of severance, and the resulting area being thus diminished, the computation shows a greater tensile strength per square inch of $\times$-section than actually existed, which fact should be kept in view in considering the resulting figures.

The specimen (No. 10) of bar iron, from which the Simonds iron bolt was made, being quite short, slipped from the clamps of the testing machine after the extension in length had commenced, and an increase of strength resulting from the intermission of strain appears.

An important feature of value in the application of this invention to the production of screw bolts, is that the shafts of such bolts can readily be made between the screw threads and the bolt head, equal in diameter to the base of the screw threads. This is important not merely as a saving of material, but is of great value in increasing the range of both elastic and ductile extensibility of the bolts, which as bolts are usually made, is limited to the breadth of the lines of the base of the threads, at which points they often break under concussive or other sudden strains; whilst in bolts having their shafts equal diametrally to the base of the threads, the elastic and ductile properties of such a length become operative as to receive and distribute the strain without injury.

The invention appears to your committee as especially valuable in its application to the making of stay bolts of boilers, the surface of the bolts being throughout, both thread and shaft, compacted and effectually covered and protected by a skin of magnetic oxide, resisting corrosion; and, in addition to this, the facility of rolling threads close to a shoulder, permits of the production commercially of stay bolts heretofore desired, but too expensive to use. A strict compliance with the regulations of the navigation laws for boiler inspection is thereby facilitated, and for this it should be highly commended.

As compared with iron, manipulated in the usual way, the sections of machine-rolled iron articles produced by the Simonds method, exhibit, when tested with acids, a skin or layer of surface metal very slow to corrode, and in steel specimens the resistance to corrosion is still more marked.

The value and prominent importance of this invention, in furnishing accurately-made forgings in large numbers of better quality than were ever before procurable, and at greatly reduced cost, impresses your committee so strongly

that they feel it incumbent upon them to report what they find to be the preceding state of the art under which this invention was made, in order that the position which this improvement is entitled to claim may be clearly appreciated.

They find, as is, frequently, if not invariably the case, preceding embryonic inventions and attempts at analogous results.

In none of these does this invention, when clearly understood, appear.

In making this search, your committee have inspected the classified series of patents in the United States Patent Office relating to this subject-matter directly, and all that the examining corps of that office thought in any degree collaterally pertinent to the subject, in examining Mr. Simonds' several applications for patents, and of every patent cited as a reference bearing upon the subject; they have, in turn, examined all patents and other references cited as bearing upon these, both foreign as well as American.

Whilst your committee are fully aware that this extent and line of examination by them is unusual, they feel that it is due to the importance of the invention, and the place it must, by its merit, occupy in the arts.

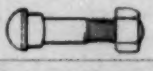
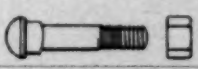
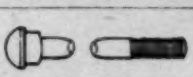
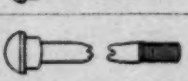
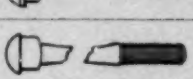
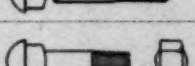
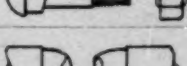
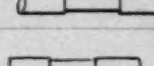
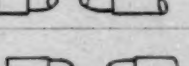
The references thus collated, with the thirteen patents of Mr. Simonds', include forty-five United States patents and nine British patents, a schedule of which, together with other publications referred to, will be found appended hereto.

It is scarcely necessary to add that many of the references cited did not relate to the method or any essential principle or feature involved in the invention, but merely to minor details in the construction of the apparatus.

From this examination your committee find, as a pre-existing state of art, a number of attempts to produce articles of circular form by rolling.

Earliest of these is that shown in the British patent No. 2,932, dated October 30, 1806, granted to William Bundy, a mathematical-instrument maker, of London, for a machine for making bullets.

RECORD OF TESTS MADE BY SUB-COMMITTEE NO.

No.	Material.	Description.	Form before Test.	Form after Test.	Square Inch Area.	
					Before Test.	A Te
1	Steel.	Simonds' Track Bolt.			. . .	. .
2	Steel.	Simonds' Track Bolt.			·328	Too irregular for
3	Steel.	Simonds' Track Bolt.			·328	
4	Steel.	Simonds' Track Bolt.			·328	
5	Steel.	Simonds' Track Bolt.			·328	·1
6	Swedish Iron.	Simonds' Track Bolt.			·343	·1
7	Iron H. & T. Track Bolt.	Head Upset.			·337	·2
8	Iron H. & T. Track Bolt.	Head Upset.			·337	·2
9	Iron H. & T. Track Bolt.	Head Upset.			·640	·6
10	Swedish Iron. Same Bar as No. 6.	Straight Bar Turned Down.			·793	·8
11	Steel. Same Bar as No 5.	Straight Bar Turned Down.			·798	·3

The nuts used in the above tests are Hoopes &

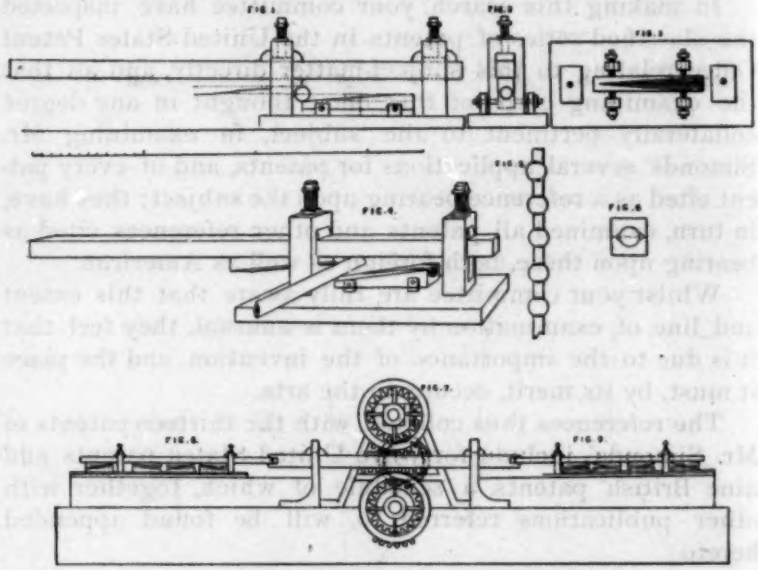
(*Committee.*)

TEE NO. 1, ON SIMONDS' ROLLED FORGING MACHINE.

Square Inches Area.		Cent. ction	Length in Inches.		Pounds Breaking Strain.	Pounds Strength per Sq. Inch. Original X Section.	Pounds per Sq. Inch. Final X Section.	Remarks.	No.
Before Test.	After Test.	on.	Before Test.	After Test.					
. . .	. . .	.	. . .	. . .	. . .	. . .	. . .	At 31,460 pounds pulled thread from nut.	1
·328	Too irregular for measurement.	.	. . .	. . .	30,360	. . .	. . .	Broken diagonally through three threads.	2
·328		.	. . .	. . .	26,730	. . .	. . .	Broke through base of one thread.	3
·328		.	. . .	. . .	27,800	. .	. . .	Stretched in all exposed threads.	4
·328	·153		4·17	4·85	22,290	67,957	115,636	Broke with cupped fracture.	5
·343	·126		4·16	5·17	14,742	43,072	117,000	Fracture with fine fibre.	6
·337	·217		4·21	4·67	18,110	57,145	83,156	Broke with oblique fracture.	7
·337	·275		4·21	4·67	17,510	51,969	63,673	Broke at shoulder.	8
·640	·617		4·15	4·38	20,430	63,645	33,512	Broke close to nut.	9
·793	·379		. . .	. . .	34,460	43,468	125,312	Fracture with fine fibre.	10
·798	·365		. . .	. . .	54,994	68 915	150,035	Fracture cupped partly in each end.	11

ests are Hoopes & T old-punched iron hexagon.

In this machine the lower die was trough-shaped and stationary, while the upper die was of a similar form, and arranged to slide in dies lengthwise over the lower one. These dies were bevelled or inclined in the direction of their length, but straight or parallel crosswise upon their edges. The lead to form the bullets was introduced between the dies in the form of a cylindric bar, laid across the lower die at the lower end, and the edges of the upper die passing over it, pressed upon the lead and forced it upon the edges of the lower die, along which it rolled to the opposite end,



Bundy's British Patent No. 2,932, of 1806.

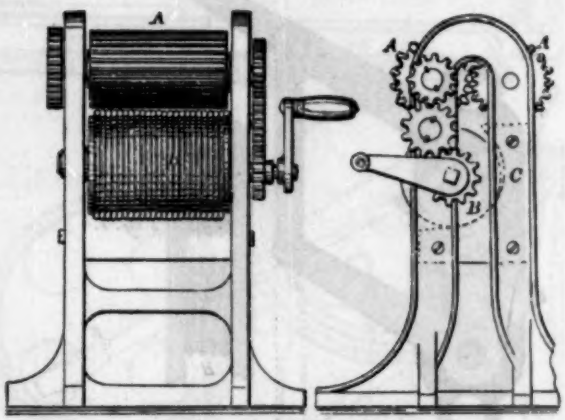
crushing it between the parallel edges of the dies, the portion, in the semi-circular trough of the dies, assuming a spherical form, and the part between the parallel surfaces of the edges acquiring a cylindric form, which was gradually reduced in diameter, until severed from the ball, leaving prominences on the poles of it."

The end view of the dies shows that the dies did not make perfect spheres, but instead balls with projecting lumps at the poles, which were to be afterward rolled down to conform to the spherical surface.

The drawing shows the balls as partially formed and united by the cylindric stem or bar; the dies in this case did not push the metal outwardly from the sphere, but pressed radially inward, forcing the metal toward the sphere, and differ from those of the Simonds inventions which force it outward.

This machine, while bearing some resemblance to that of Mr. Simonds, worked imperfectly in lead and was inapplicable to iron.

Bruff's bullet compressing machine, which we here reproduce as illustrated in Knight's *Dictionary of Machines*, vol. 1, page 403, made leaden spheres, by rolling

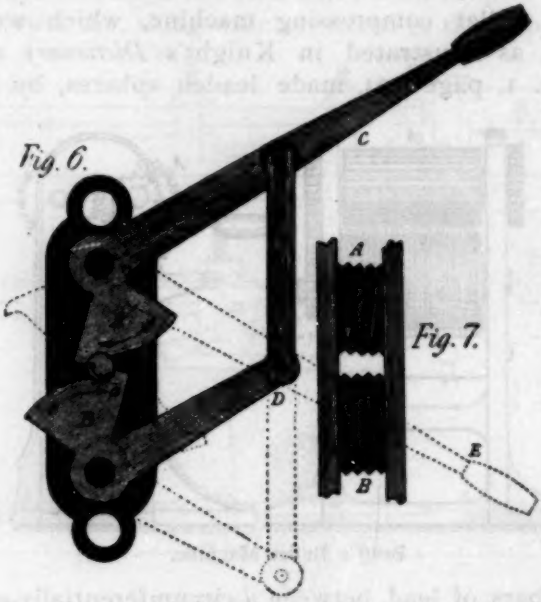


Bruff's Bullet Machine.

cylindric bars of lead between a circumferentially-grooved revolving cylinder and a converging concave surface having corresponding grooves. In this case, the lead is compressed lengthwise in the direction of the axis of the bar, so that the diameter of the bar required was less than that of the resulting sphere. The metal, in spheres compacted by this machine, was not subjected to as much pressure at the central band as at the poles. In this device the metal is compressed and shortened in the direction of the axis of the bar, and enlarged diametrally, which is the reverse of the operation of the Simonds rolling dies. Neither of these inventions appear to have been applied to other materials

than lead, and while having some semblance to the invention under consideration, are essentially different, and do not contain the invention under consideration.

In a publication, dated 1822, Manchester, England, entitled *James White's New Century of Inventions*, there appears on plate 19, in *Figs. 6* and *7*, and described in pages 60 and 61, a machine or hand implement, designed to roll circular objects including screw threads. A copy of the drawing is here



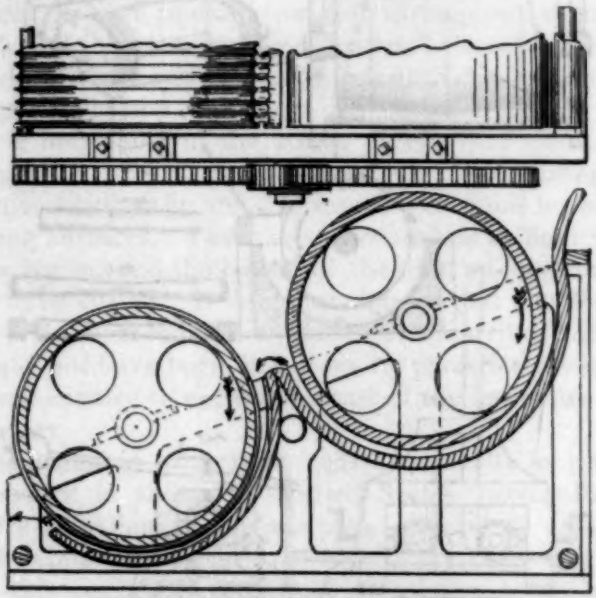
Jas. White's Rolling Machine, Manchester, Eng., 1822.

shown. A full copy of the text of his description will be found in the appendix to this report.

While this recognizes the fact that screw threads diverge as they are rolled, it fails to show that the lengthening of the article to shape must be accomplished by a bevel on the edge on the working faces; in fact, it shows nothing more than two parallel involute faces, opposed to each other, and vibrated simultaneously by a lever handle and connecting links, the section showing threading grooves. The inventor does not appear to have ever made or tried the device, but

simply described it and suggested applications of it in the arts.

Machines operating similarly to Bruff's, made by the late Reese J. Hollingsworth, machinist of this city, and known as "pill" machines, have been in use in the cracker bakeries of Philadelphia since 1852. These were used to make balls of dough with a rolled "skin surface" from which water crackers were made. A partial top view and vertical section is here shown.



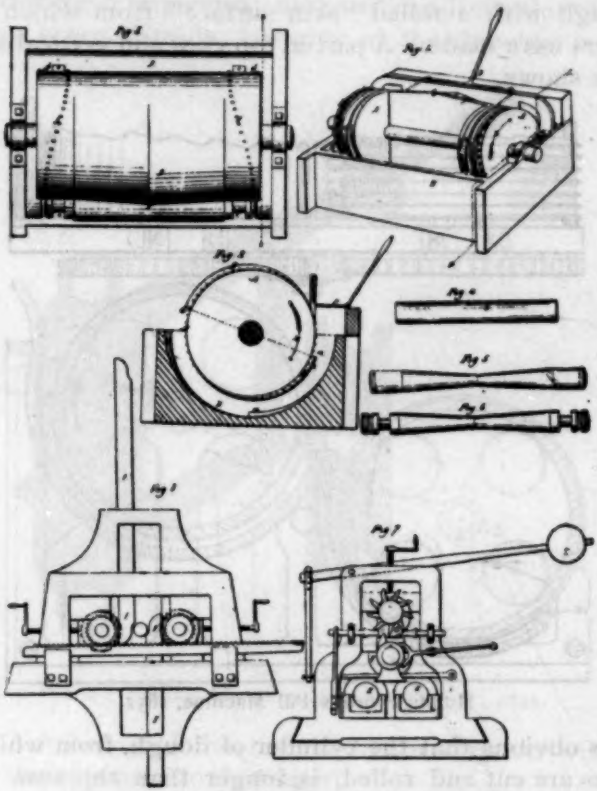
Hollingsworth's Pill Machine, 1852.

It is obvious that the cylinder of dough, from which the spheres are cut and rolled, is longer than the sum of the diameters of the balls produced from it, and is of less diameter than the balls, requiring an upsetting or shortening to form the ball, and in this respect it differs from the Simonds machine in principle.

While the materials operated on in these machines are so different from iron and steel, the resemblance of parts used is considerable and suggestive of the constructions used for metal working; in fact, the practice of mechanics in making

models of machines for rolling, forging and stamping ductile metals is to test them when in course of construction, with clay, dough, wax, putty and lead.

Having these machines in view and such practice in mind, the resemblance of the invention described and shown in United States Letters-Patent No. 10,460, dated January



Jacob Reese's U. S. Patent, No. 10,460, of 1884.

24, 1854, for rolling axles and shafts, granted to Jacob Reese, becomes apparent, as will be seen in the drawing which is here shown.

Here is a showing of oppositely moving reciprocating tables; three rollers between which an axle was to be placed and means for pressing the upper roller down and convex series of dies turning in concave series, which are

described as "converging" and "properly shaped," but they lack the necessary inclination of the edges of the working faces to draw the metal, being in fact converging profiles fitting the shapes of parts of the desired axle.

Such converging faces being parallel with each other in the direction of the axis of the bar, could only press radially upon the bar, and have been demonstrated to be incapable of useful operation.

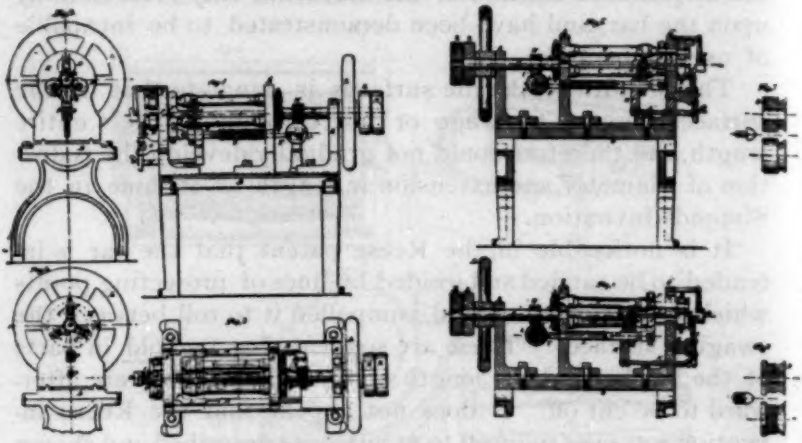
The breadth of the die surfaces is equal to that of the surfaces they are to swage or roll throughout their entire length, and therefore could not gradually develop the reduction of diameter and extension in length as is done in the Simonds invention.

It is noticeable in the Reese patent that the bar is intended to be carried and guided by lines of projecting points which, indenting the metal, compelled it to roll between the swaging surfaces. These are so located as to hold in parts of the bar beyond the length of the axle, which were afterward to be cut off. It does not appear that the Reese invention was ever reduced to practice; as described and shown it could not have been, but from its plausible resemblance it seems entitled to notice as a part of the preceding history of the art.

The reducing of metallic rods diametrally by rolling to form rivets, is shown in United States Letters-Patent to Charles B. Allen, of Philadelphia, numbered 22,843, and dated Febuary 8, 1859, the drawing of which is here shown.

In this machine, a rod, equal in diameter to the greatest diameter of the intended rivet head, was reduced by rolling between three equi-distant revolving rollers, which were gradually pressed toward the axis of the bar, the form of the rollers being a profile of the rivet. The rivet when formed was severed from the rod by a revolving cutter, or circular saw pressed against it. The extension of the metal in this machine was due entirely to the diametral pressure made upon it, and not to any direct drawing process, the compression to reduce the diameter being made throughout by the same instrument that finished it. This invention was slow in operation and never attained a permanent place in

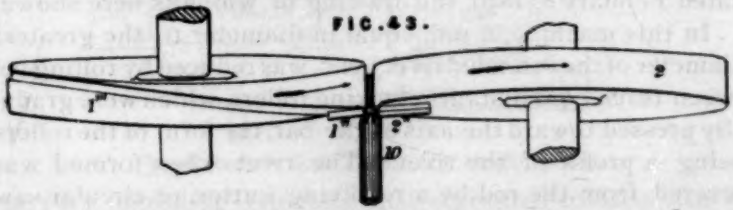
the arts. Among the later inventions that have been suggested as resembling that of Mr. Simonds, is that shown in British patent No. 3,677, dated December 20, 1869, granted to James Robertson, of Glasgow, Scotland, for rolling balls and rivets from rods. In this two rollers, placed with their



C. B. Allen's U. S. Patent, No. 22,843, of 1859.

axes slightly inclined from parallel position with each other, were turned and grooved upon the face, so that the space between them was of the same form and size as the lengthwise central section of the desired forging. The wheels were rotated in opposite directions.

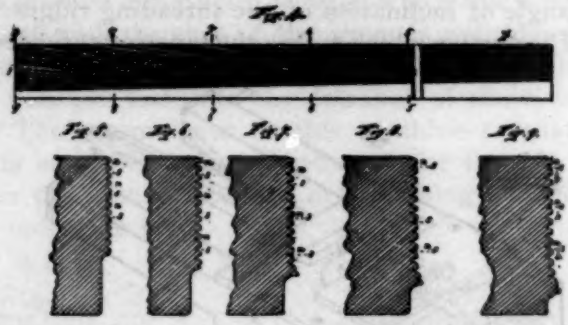
FIG. 43.



Robertson's British Patent, No. 3,677, of 1869.

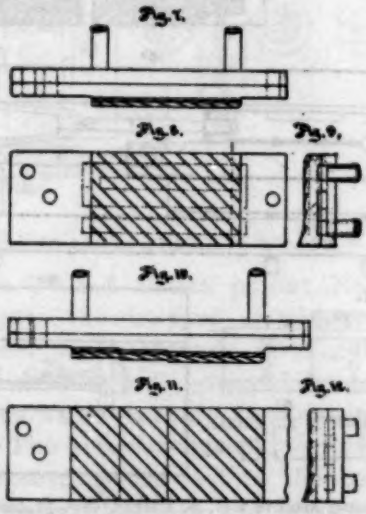
The action of this apparatus was almost entirely by compression in the direction of the diameter of the rod, the drawing or stretching effect due to the inclination of the axes of the wheels being very slight, this invention does not appear to have reached any commercial success.

Among the patents referred to, as recognizing the extension in length during the rolling operation between dies, is Edward Croft's re-issued United States patent No. 5,673,



E. Croft's U. S. Patent. Re-issue, No. 5,673.

dated December 2, 1873, which shows dies with diverging oblique ridges and grooves, shown in the figure marked *4*, copied from that patent, but no attempt was made to give

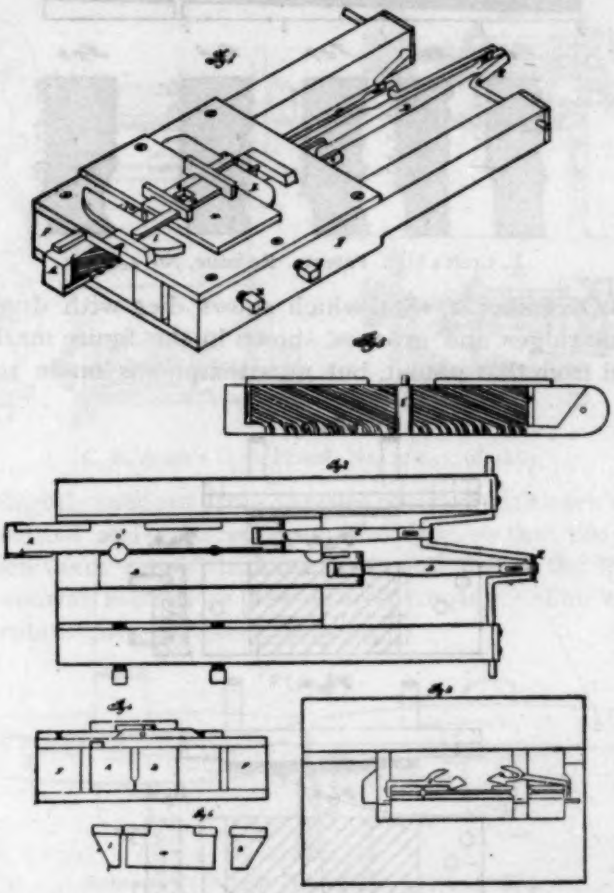


J. M. Alden's U. S. Patent, No. 110,532, of 1870.

any other shape to the articles by rolling, but stopped at simply impressing threads upon them. Dies, for hot rolling threads upon iron screw blanks, also appear in J. M. Alden's

United States patent, No. 110,532, dated December 27, 1870, for wood-screw machine, figures numbered from 7 to 12, which are here shown.

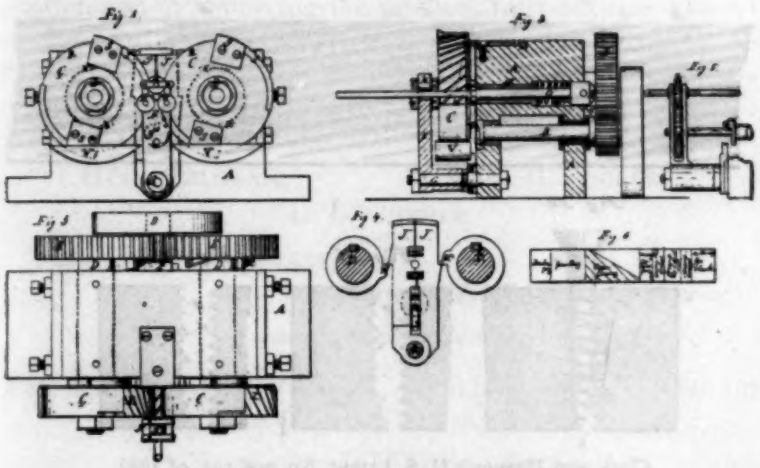
The angle of inclination of the threading ridges is uniform. The portion which makes the tapering threaded point



Harwood and Mickle's U. S. Patent, No. 72,490, of 1867.

of the screw is described as cutting the metal away to make the taper, by the sharp end of the die shearing the metal off as the die swages a part, and cuts off a part before rolling the point, the pressure at the end in these dies tending to shorten or upset the metal.

An earlier United States patent, that of Harwood and Mickle, numbered 72,490, and dated December 24, 1867, illustrated opposite, shows dies for threading screws, having oblique grooves and ridges between which the screws were rolled, and with the ends of the grooves and ridges carved, so as to produce a greater pitch in the threads of the screw at the point, to facilitate the entrance of the screws into wood. The resemblance in this machine to that of Mr. Simonds ceases with the indenting of the thread; there is in it no pretence of drawing or stretching the metal, but simply indenting it.

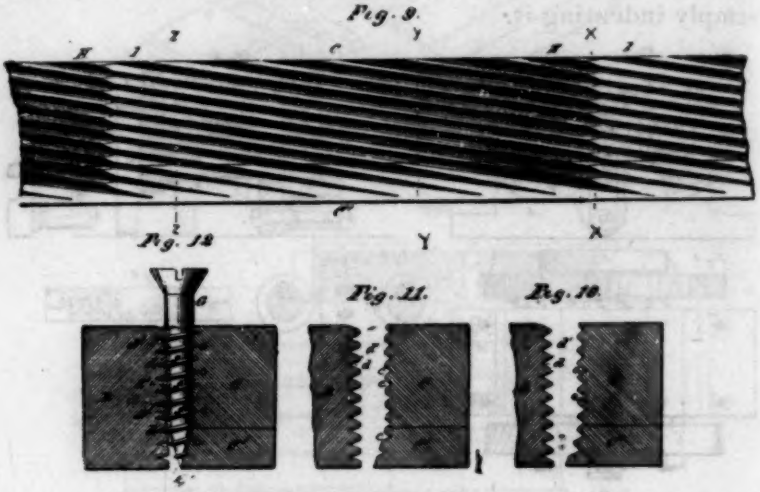


R. Boeklen's U. S. Patent, No. 109,171, of 1870.

R. Boeklen's United States patent No. 109,171, dated November 15, 1870, the drawing of which is above shown, simply impresses screw threads upon cylindric rods, by rolling them between spirally-grooved cylindric rollers, with their contiguous faces turning in opposite directions on parallel axes. The screws, thus made, have heads formed on them by upsetting the rod in the usual manner for making rivet heads; this, like the preceding device, only resembles the Simonds invention in rolling the screw threads, instead of cutting the metal from between them.

In the invention of Clark and Harvey, shown in United States Letters-patent, No. 306,132, dated October 7, 1884, the

threads of wood screws are rolled in them by a concavely-curved stationary and helically-grooved die, the face of which converges toward a revolving correspondingly helically-grooved die, in which the threads gradually deepen from two opposite points in the circumference. A projection in a plane, of the cylindric face of the revolving die, is here shown, marked *Fig. 9*, taken from the drawing of that patent, and also a section, marked *Figs. 10, 11* and *12*, showing the stationary die, marked *D*, and the revolving die, marked *E*.



Clark and Harvey's U. S. Patent, No. 306,132, of 1884.

In none of these does anything further appear to have been attempted, than the indenting of threads by pressure upon the revolving metal, and the crowding of the metal displaced from the groove, into the crest or ridge of the screw-thread, such a feature as drawing the metal by oblique forging surfaces, in the direction of the axis of the bar, nowhere appears; the method of working metal disclosed in Mr. Simonds' patents is so far as your committee can discover entirely original with him.

In conclusion your committee refers to a paper, read by the inventor at the June meeting of the INSTITUTE and published in the July number of the JOURNAL, in which such a clear

account of his conception and development of this invention is given, that it would be a trespass upon patience to restate it in this report. After a careful examination of the invention and all collateral information seeming to bear upon the subject within reach of your committee, they are fully warranted in the conclusion that the entire credit of originating and perfecting the method or system herein described, of metal forging by rolling shapes, without impairing the quality of the work by upsetting, belongs to Mr. Simonds, and that the high degree of perfection to which he has brought this new art, both in facilitating production and in improving the product, fully entitles him to recognition by the highest award in the gift of the FRANKLIN INSTITUTE, viz: the ELLIOTT CRESSON MEDAL.

Respectfully submitted,

S. LLOYD WIEGAND, J. SELLERS BANCROFT,
HUGO BILGRAM, JOHN H. COOPER,
L. L. CHENEY.

Adopted October 3, 1888.

GEORGE A. KOENIG, *Chairman.*

THE RELATIVE VALUE OF ALUMINIUM AND ITS ALLOYS IN THE ARTS.

(A CORRECTION BY MR. PEMBERTON.)

In the article on "Aluminium and its Alloys," published in the October impression of this JOURNAL, the statement was made that the United States Government had countermanded the order for manganese bronze for the construction of propeller blades, and had adopted aluminium brass in its stead. This statement was taken from a letter, by Mr. Eugene H. Cowles, to *Engineering*, appearing in its issue of June 1, 1888. As a matter of precaution, however, the entire paper on the subject was submitted to Mr. Alfred H. Cowles, but, unfortunately, owing to his absence from Lockport, did not reach him early enough to allow him time to

reply before publication. He writes me that the Government has "accepted our No. 3 aluminium bronze for this purpose, but still leaves the contractors free to use manganese bronze if they so desire. It results in our having to furnish the aluminium bronze with very high strength specifications in competition with manganese bronze with no strength specification stipulated, and at the same price. We are now making the wheel for the gun-boat *Petrel*."

H. PEMBERTON, JR.

ON THE DISTRIBUTION OF INTERNAL FRICTION OF ENGINES.*

BY ROBERT H. THURSTON, Ithaca, N. Y.

INTRODUCTION.

In earlier papers, read at various times before the American Society of Mechanical Engineers, the writer has called attention to the fact that the variation of load in steam-engines is not productive either of the method or of the amount of engine friction that has been commonly assumed by earlier authorities on that subject.† It was shown that the formula of De Pambour, which makes the internal friction of the engine proportional to the load on its piston is not usually correct, and probably is never so, with any familiar form of engine, or under any conditions often met with in practice. It was further shown that, under the conditions of usual practice, and at all ordinary speeds and pressures of steam, the resistance of the engine itself, its internal friction, remains sensibly constant, and that the so-called friction-card of the machine represents practically the friction of the engine when fully loaded, the indicated power without load being sensibly the measure of the

* Read at the Scranton Meeting of the American Society of Mechanical Engineers, October 15–19, 1888.

† "Friction of Non-condensing Engines." *Trans.* Vol. viii, No. ccxxviii and Vol. ix, No. cclxv.

wasted work of the engine when in operation under load of whatever amount.

The literature of this branch of the subject of steam engineering is very meagre, and the results of experiment in this field, if any have yet been systematically made, are not recorded in any works as yet consulted by the writer. The very natural supposition that the friction of an engine is always composed of two parts, the one the friction of the engine unloaded, a constant, and the other a quantity measuring the added friction due to the imposition of the load, and variable directly with that added load, seems to have been accepted by all writers from De Pambour, the first to attempt to consider the subject, to the period of investigation by the writer. On the other hand, however, engineers familiar with the operation of the engine have been accustomed to take a diagram with the steam-engine indicator, the engine being unloaded, as representative of the friction of the machine at all times. This was probably taken as so representative simply because it was usually impossible to obtain any measure of friction of loaded engine, and the friction-card was thus the best approximation that could be secured. Rankine would seem to have suspected that the assumed formulas of De Pambour might not be exact, as he remarks, "Our knowledge of the amount of energy so lost is still very vague and indefinite;" but he also states (*Steam Engine*, art. 292) that "in most cases which occur in practice, a result nearly agreeing with that of the preceding formula, is obtained by supposing that the whole of the prejudicial resistance is proportional to the useful load." De Pambour gives the value of the coëfficient by which the load is multiplied as about 0·14, and Rankine asserts this to agree with practice. Weisbach attempts to produce a formula for this waste, assuming Morin's values of coëfficients of friction, but his results are very greatly in excess of those to be given as determined by investigations made to ascertain its amount by experiment; they also seem to be based upon entirely inaccurate assumptions, and are evidently quite as unreliable as are those of De Pambour and Rankine.

The first investigation undertaken systematically to determine the law and the methods of waste by internal friction in the steam-engine were, so far as yet known, those directed by the writer, the scheme being the securing of constant conditions, except in the one direction in which variation was to be produced, for the purpose of noting the extent and the law of variation of friction with variation of the one element studied. Thus: the engine was placed under the usual and standard working conditions, but without load, and a friction diagram was taken as a measure of the power wasted in friction of engine alone. The conditions being kept constant in all other respects, the load on the engine was varied from this minimum up to and beyond the maximum rated power of the machine, and the indicated compared with the dynamometric power in every case, the difference measuring the engine friction for that power and load. In other cases, the speed of the engine varied, the power and all other conditions being kept constant; the same method applied when the power, speed, steam pressure and other conditions were held constant, except that the method of distribution of steam was varied, and the results of such a series of tests were then compared with those otherwise obtained. In still other instances the steam pressure was made the variable element, or the ratio of expansion and point of cut-off, the indicated and dynamometric power being in each case compared as before to obtain a measure of the engine friction. By this systematic method it was anticipated that in time a correct theory and exact formulas might be produced. This expectation has not been wholly disappointed; but the results of the investigation, while eminently satisfactory, have proved to be quite opposed to the original assumptions of the older writers, and in most perfect accord with those of the practitioners.

The first of these series of experiments to be made in so satisfactory a manner as to justify publication, were those conducted under the supervision of the writer, in the winter and spring of 1883–4, by Messrs. Aldrich and Mitchell, and published in a paper read before the American Society of

Mechanical Engineers in the autumn of 1884.* The engine employed was a Straight Line Engine, constructed under the eye of its inventor, Professor John E. Sweet, past President of the Society, and representing well that type of engine. These experiments showed unmistakably the error of the older formulas, and revealed the unexpected fact that, in that class of engines at least, the internal friction does not vary with the addition of load, but remains constant, so far as could be detected, at all loads. The method of lubrication and its efficiency, the variations of steam pressure and of speed, slight as they were, were accidental causes of change of engine friction, having very much greater effect on the total than a variation of the power of the engine from that marking its resistance to motion, unloaded, up to the full rated power of the machine, and even far beyond the latter amount. The engine had been carefully designed with the special intent to make engine friction as low as possible, and the loss by friction at its rated power was but about six per cent. It came down to about five per cent. at the maximum power demanded of it, varying almost precisely in inverse proportion to the indicated power. The "friction-card" was a measure of the friction of the engine at all loads.

This research was again undertaken at the request of the writer, in the winter and spring of 1885, by Messrs. Day and Riley, of Sibley College, Cornell University, employing a similar engine, built under the supervision of the inventor in the workshops at that school. The outcome of these investigations, which have also been recently fully reported and widely published in this country and in Europe, was thoroughly corroboratory of the previous conclusions. No measurable variation of the total internal friction of the engine could be traced to the variation of engine power and load. Studying the effect of variation of steam pressure, it was found that some slight alteration was produced, the friction increasing very slowly as pressures were increased, but not in any important degree. These data have been since revised by Messrs. Carpenter and Preston, and it has

* *Trans. A. S. M. E.*, Vol. viii, page 86.

been found that the change of friction with variation of steam pressure may be taken as insensible after passing the ordinary minimum working pressure of engines, the variation being observable only from about fifty or sixty pounds per square inch downward. It having been also suggested that the method of steam distribution might produce some change in the law exhibited by the types of engine having automatic adjustment of expansion by the action of the governor, Messrs. Gillis and Buchanan, in 1887, undertook, under the direction of the writer, to settle this question by experiments upon the engines of similar type, as employed in the mechanical laboratories of the Sibley College. These experiments fully confirmed those which had previously been made, and showed sensibly constant friction at all powers and loads, whether the engine was regulated by the automatic system, or by a governor operating the throttle-valve in the steam-pipe or at the steam-chest.

We are now brought to the study of the latest, and as yet unpublished, experiments made to determine, with some degree of exactitude, the *method of distribution of internal friction*, and, further, to ascertain whether all engines are subject to the same law as has been found to control the high speed engines previously employed in these researches. These last investigations were made with this object in view by Prof. R. C. Carpenter, of Lansing, Mich., and Mr. G. B. Preston, of Sibley College, as observers, experimenting first with the engines of the college laboratories, and later with other machines of various types in and near Lansing. Earlier experiments had shown the engine friction to be independent of the load, but to be a function of the characteristics of the engine itself, of the speed of piston and rotation, of the steam pressure, and of the method of steam distribution, the two last-named conditions having slight effect, the others being most important. The weight and design, and the character of the workmanship of the engine, primarily determine the amount of its internal friction; the resistance is also a direct function of its speed, and it is slightly and observably affected, within limits, by the steam-pressure variations, and by the character of valve-gear and

of steam distribution and of regulation of engine. The speed and weight of the running parts of the engine may, so far as can now be ascertained, be taken as the elements controlling friction of the machine. The details of all this earlier work have been given at sufficient length in the earlier volumes of the *Transactions of the American Society of Mechanical Engineers.*

It now becomes an interesting and a vitally important problem to determine just how this friction of engine is distributed among its various moving parts, its journals and guides, stuffing-boxes and piston-rings. This has hitherto been regarded as a problem incapable of solution, since it was presumed that the total and the elements of the internal friction of engine would be so seriously variable with the alteration of load, that it would be impossible to measure the friction of the machine, part by part, and to sum up the whole correctly. It having been found, however, that the internal friction of the engine is invariable in any measurable or important degree with variation of power, and that the so-called "friction-card" is a measure of the friction of the engine at all powers, the speed being constant, it is at once evident that we may now proceed to analyze the several parts of this total by analyzing the engine into its various friction-producing elements, and measuring up the several elements of the total friction, each by itself, and summing all for the total. The discovery of the sensible constancy of the total friction thus affords a new means and method of investigation. This accomplished, also, it becomes possible, knowing as we now do, the quantities of friction at each point of "pairing" of elements, as Reuleaux would say, and it becomes easy to determine just where the most serious wastes of energy and power are met, and thence, just in what direction we are to study the design and construction of the machine with a view to the reduction of these wastes most promptly and effectively. The improvement of the efficiency of the steam-engine is to be now effected very largely by its improvement as a piece of mechanism, and nearing, as we now are, the limit of the perfectibility of the engine thermodynamically, the engi-

neer is compelled to look in this direction for further opportunity of advancement. The thermodynamic efficiency of the engine has attained, in the best of modern engines, very nearly its maximum under familiar working conditions; the efficiency of the engine as a machine still offers some little chance of gaining upon the existing conditions of best work. The thermodynamic wastes are now by the best designers and constructors reduced to about ten per cent. in large engines, while the friction wastes of the machine are usually considerably more in that class of engines, though less in the simpler and lighter engines of the recent high-speed type.

The plan adopted in the series of experiments to be described, in which Messrs. Carpenter and Preston proposed to endeavor to effect an analysis of the total internal friction of the steam-engine, and to ascertain in what proportion it is distributed to piston and cross-head, crank-pin and shaft, valve-gear and guides, was first to determine the friction of the machine in the manner already practised by them and by their predecessors in this work, then to dismantle the engine, part by part, driving the connected parts by a pulley and belt from the main line of shafting overhead, through a transmitting dynamometer carefully standardized, and thus to secure measurements of the resistance of part after part until all the rubbing parts having been thus examined, the sum of their resistances at the normal speed of the engine should give the total internal friction of the engine and the percentages of the whole due to the resistances of each point of connection or rubbing. In each experiment the endeavor was made to secure precisely the conditions of operation, so far as was practicable, which were usual in its regular working. For instance: the engine was always heated up by its own steam when the resistances of the piston and the valves were to be measured; the speed of engine was kept the same when testing the friction of journals as when it was doing its full work; the valve, balanced and unbalanced, was tested under the usual boiler pressures, as well as unloaded, and exactly as possible, and thus every precaution that could be devised was adopted to secure

precisely the results that should be observed, were such observation possible, when the machine was at work. The engine was first driven by the shafting, and through the dynamometer, with everything connected and the cylinder heated up to its usual temperature by a run, immediately preceding, under steam, the cylinder heads and steam-chest cover only being removed to prevent any pump-like action of the engine while so driven. Next, the piston was disconnected, and the power demanded to give the engine its regular speed was observed with all other parts connected and moving; thus obtaining a measure of the friction of the piston alone, by differences. Then the next point of connection would be broken, and another observation would give the friction of the next successive piece, and so on until the whole engine had been gone over, when the machine was assembled again, part by part, and thus a check obtained on the previous determinations.

The first step of importance was to secure a good standardization of the transmitting dynamometer to be employed in the work. This method required the use of a transmitting dynamometer of great accuracy. Sibley College possesses a number of such dynamometers, the accuracy of each of which was tested by comparison with a Prony brake, and also by lifting a known weight through a given space. The best result was given in each case by a dynamometer of the Morin type, built in the Sibley College shops. The principle governing its action is very simple, and is shown clearly in *Fig. 18*. A pulley of which the rim *B* is shown, is fitted loose on the shaft *S*. Four flat springs are securely bolted to the shaft *S*, and to the rim *B*. Now, if force be applied by a belt around *B*, to turn the pulley, and if resistance to its turning be produced by a fixed pulley on the shaft *S*, from which some machine is driven by the belting, the springs *c* will be deflected into new positions c^1, an amount proportional to the force, and the fixed pulley will then revolve, thus driving the machine. To show the amount of power transmitted, and any variation that may occur in that power, a pencil is attached to the rim of the pulley, or to a post having an equivalent

motion, and a recording apparatus, consisting of a series of gear-wheels actuated by a spiral thread on a sleeve on the axis, causes a band of paper to move radially under the pencil. The recording apparatus can be stopped or started at will, without interfering with the motion of the machinery, by causing the loose sleeve to engage with a lug on the shaft. The results obtained with this dynamometer agreed closely with those results obtained by the Prony

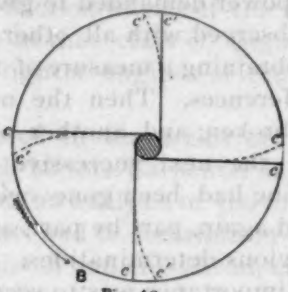


Fig. 18.

brake, and by moving a known weight through a given space. The diagrams obtained from the dynamometer consisted of a series of waving lines of varying elevation and with different average ordinates. The undulations were produced by changes of speeds probably caused by the inequalities of belt lacings, etc.

The general appearance of these diagrams is shown in *Fig. 19.*

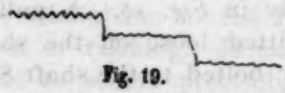


Fig. 19.

The dynamometer was calibrated three times: (1) By attaching a brake to the same shaft, and comparing the diagrams with the brake readings. (2) By direct pull with a spring balance against the springs of the dynamometer and thus obtaining the ordinate for a given belt-pull. (3) On the same principle as the first, but a spring balance was used, to measure the brake weights, instead of scales. The object of these calibrations was to obtain the ordinate

corresponding to any given belt-pull. The following results were obtained:

CALIBRATION OF DYNAMOMETER.

Comparison with Prony Brake.

First Trial—Brake pulling against load of 52 pounds on Fairbanks Scale.

Scale Load.	Brake Load. Pounds.	Pull on Dynamometer Pulley.	Ordinate in Inches.
2	50	67·1	3·10
6	46	61·7	3·00
11	41	55·0	2·90
16	36	48·3	Lost.
21	31	41·6	2·06
26	26	34·9	1·75
27	25	33·5	Lost.
31	21	28·2	1·57
36	16	21·5	1·30
41	11	14·8	1·25
51	0	0·	0·4

Second Trial—Brake pull measured by a spring balance.

	5	6·7	0·54
	10	13·4	0·92
	15	20·1	1·23
	20	26·9	1·58
	25	33·6	1·80
	30	40·3	2·16

The diameter of the brake pulley, including belt, was 23⅛ inches; the dynamometer pulley, including belts, was 17⅛ inches.

CALIBRATION ON DYNAMOMETER.

(2) Method, by direct pull against springs of dynamometer.

This method was employed a number of times, and gave uniform results, the variations from the results of this trial and the first and third, as previously given, are believed to be errors incident to the use of the brake.

Pull on Dynam. Pulley. Pounds	Ordinate Inches.	Pull on Dynam. Pulley. Pounds.	Ordinate Inches.
0	0·40	35	1·80
5	0·65	40	2·08
10	0·80	45	2·32
15	1·08	50	2·58
25	1·33	60	3·08
30	1·55	70	3·52

The mean of these three results corresponds very closely to this last, and, where plotted, gives a straight line, whose equation is

$Y = 0{\cdot}046 + 0{\cdot}20$, Y being expressed in inches and X in pounds.

The diagram of the curves is shown, and interpreting the results was used instead of the equation. (See *Fig. 20.*)

The engines employed in the investigation to be described were of several types and of various sizes, styles and proportions. The first was a small straight line engine, built in the Sibley College workshops, but modified from time to time for purposes of experiment, in such manner that it represented the ordinary type of directly connected engine with throttle regulation. It was tried, both with its usual balanced and with an unbalanced valve. Another engine was a traction engine, built by the Lansing Iron Works, with locomotive style of valve motion; and others,

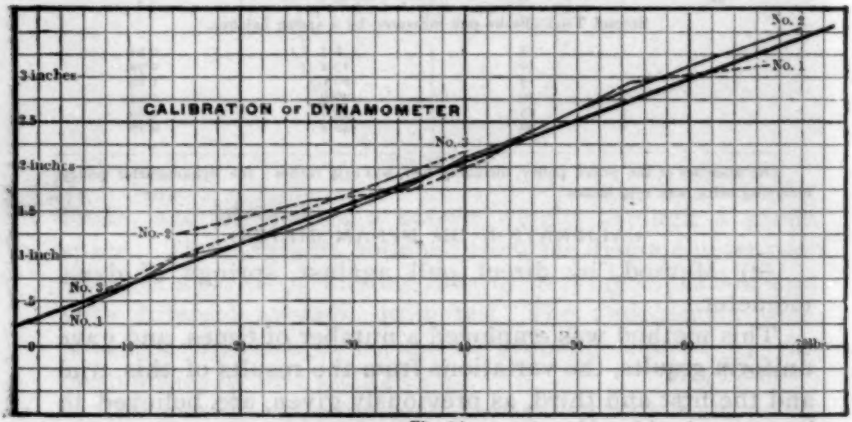


Fig. 20

by the same company, were of the automatic type, and compound and condensing engines, both the latter having balanced valves.

FRICTION OF STRAIGHT LINE ENGINE.

The first engine tested was the 6 x 12-inch straight line engine built by Prof. J. E. Sweet, while connected with Sibley College. This engine has been modified for experimental purposes in many ways, but still retained the principal characteristics of the straight line engine. The valve-gear is arranged for a fixed cut-off at any part of the stroke less than five-eighths, and the valve can be changed by

removing the pressure-plate and fastening on a back, from a balanced valve to an ordinary slide-valve.

For these tests the power was obtained from the water-wheel and main driving shaft in the Sibley College shops, the speed of which was not always uniform and was beyond the control of the investigators. The power was measured by passing it through the transmitting dynamometer. The speed was measured by a hand-speed indicator and also by an attached tachometer, which had been carefully calibrated. The tachometer results could only be used to correct errors, as readings to single revolutions could not be made.

In making this trial, and all others, the engine was first heated up by steam, the steam-chest cover and cylinder-heads were removed to prevent pump action, then, as quickly as possible, the dynamometer cards were taken. These diagrams were generally taken with the engine complete, and then successive cards with part after part removed. The engine was turned by power applied to its main driving-wheel. The speed of the engine varied from 200 to 244 revolutions, and the results were corrected in accordance with the law, known to be true for that engine, that the friction varied directly as the speed. This correction, however, did not seriously change the results. Twenty-nine successful dynamometer cards were obtained, each of which may be considered as the average of several observations. The practical condition of working of a plain slide-valve, with steam on, could not be obtained in these trials, because the cylinder was open to the air, and the friction obtained is no doubt too high for that particular case.

Table I presents a record of the distribution of friction found in this engine, and all essential data from later comparisons with other results from tests of the various engines afterward employed.

Table II exhibits the method of variation of friction, and Tables III and IV its computed amounts.

TABLE I.—Distribution of Friction.

Straight Line Engine 6″ x 12″. Log of Trial with Morin Dynamometer.

Number.	Ordinate.	Pull in Pounds.	Revolutions per Minute.	H. P. Developed.	H. P. ÷ Revolutions.	H. P. Corrected for 230 Revolutions.	Steam Pressure in Engine.	Condition of Engine.
1	1·78	34·5	208	1·556	·007	1·710	0	Engine Complete. Warmed up by steam. Cylinder-head off. Steam-chest cover and pressure-plate off. All cocks open.
2	1·87	36·5	205	1·622	·008	1·822	0	
3	1·86	36·5	205	1·622	·008	1·822	0	
4	1·20	22·5	230	1·122	·005	1·122	0	Piston and piston-rod dropped.
5	1·25	23·25	232	1·169	·005	1·159	0	
6	1·27	23·8	244	1·259	·005	1·189	0	Pressure-plate and steam-chest cover replaced.
7	1·28	24·0	245	1·275	·005	1·200	40	
23	2·04	39·0	186	1·573	·008	1·925	45	Balanced valve converted into slide-valve. Steam pressure on back of valve.
24	1·90	37·0	186	1·492	·008	1·844	45	
25	1·82	35·0	201	1·525	·007	1·728	42	
26	1·81	35·0	214	1·624	·008	1·752	39	
27	1·92	37·5	201	1·634	·008	1·868	37	
28	1·67	34·0	217	1·599	·007	1·690	74	
30	1·19	22·5	229	1·117	·005	1·112	0	Slide-valve, piston and rod still off.
31	1·80	34·75	218	1·642	·0075	1·732	74	
32	1·07	19·5	205	0·867	·004	0·967	0	Main shaft and eccentric.
33	1·03	18·5	207	0·830	·004	0·922	0	
34	1·00	17·5	228	0·865	·004	0·873	0	Eccentric-strap made as loose as possible.
35	0·95	16·5	225	0·805	·004	0·825	0	
36	1·10	19·5	227	0·960	·004	0·972	0	Connecting-rod attached to crank-pin.
39	1·26	23·0	215	1·072	·005	1·147	0	Engine complete except piston and rod. Slide-valve attached. Cylinder hot.
40	1·84	35·0	198	1·502	·008	1·758	75	
41	1·29	24·0	222	1·155	·005	1·195	0	
42	1·92	37·5	211	1·715	·008	1·867	67	
45	1·24	23·0	223	1·112	·005	1·147	0	Slide-valve dropped. Valve-rod still attached.
47	1·39	26·0	222	1·251	·006	1·299	0	Balanced-valve. Pressure-plate and cover off.
48	1·28	23·5	220	1·121	·005	1·171	0	
43	1·29	24·0	224	1·165	·005	1·195	0	Pressure-plate and cover added.
44	1·22	22·5	228	1·112	·005	1·222	58	

TABLE II.—Summary of the Log.
Distribution of Friction.
6″ × 12″ Straight Line Engine.

Symbol.	Number.	Friction H. P.	Average F. H. P.	Parts of the Engine producing Friction.
A	34 35	0·873 0·825	0·849	Main journals.
B	32 33	0·922 0·966	0·944	Eccentric-strap and main journals.
C	36	0·972	0·972	Crank-pin and main journals.
D	30 41 43 45	1·122 1·195 1·195 1·149	1·165	Cross-head and pin, crank-pin, eccentric and main journals.
E	40 42 23 24 25 26 27 28 31	1·758 1·867 1·925 1·844 1·728 1·752 1·868 1·690 1·732	1·798	Plain slide-valve, cross-head and pin, crank-pin, eccentric and main journals, with steam on.
F	43 6	1·195 1·189	1·192	Condition D, with balanced valve and pressure-plate added.
G	7 44	1·200 1·222	1·211	Condition F, with steam pressure.
H	1 2 3	1·710 1·822 1·822	1·785	Engine complete with balanced valve. No steam pressure but engine hot.
I	4 5	1·122 1·159	1·140	Condition D, with balanced valve added but pressure-plate off.

TABLE III.—Computation.
Distribution of Friction.
6″ × 12″ Straight Line Engine.

Combination of Conditions.		Result H. P.	Individual Part to which Friction is Due.
Algebraic Work.	Arithmetical Work.		
A	·849	0·849	Main journals.
B — A	·944 — ·849	0·095	Eccentric-strap.
C — A	·972 — ·849	0·123	Crank-pin.
D — C [B — A]	1·165 — ·972 — ·095	0·098	Cross-head and pin.
E — D	1·769 — 1·095	0·631	Slide-valve, steam on.
G — D	1·211 — 1·165	0·046	Balanced valve, steam on.
H — F	1·785 — 1·192	0·593	Piston and rod.

* Symbol of condition in column of algebraic work explained in previous table. Diameter of main journals, 3 inches; weight in main journals, 1,500 pounds.

TABLE IV.—Percentage of Total Friction and of Rated Power.

6″ × 12″ Straight Line Engne, 20 H. P.

Parts of Engine.	Engine with Slide Valve.			Engine with Balanced Valve.		
	Friction H. P.	Per Cent. of Total Friction.	Per Cent. of Rated Power.	Friction H. P.	Per Cent. of Total Friction.	Per Cent. of Rated Power.
Main journals,	0·849	35·4	4·2	·849	47·1	4·2
Eccentric-strap,	0·095	4·0	0·5	·095	5·3	0·5
Crank-pin,	0·123	5·1	0·6	·123	6·8	0·6
Cross-head and Wrist-pin,	0·098	4·1	0·5	·098	5·4	0·5
Valve (steam on),	0·631	26·4	3·2	·046	2·5	0·2
Piston and Rod,	0·593	25·0	3·0	·593	32·9	3·0
Total,	2·389	100·0	12·0	1·804	100·0	9·0

LANSING ENGINE TRIALS.

Distribution of Friction, 12″ × 18″ Automatic Engine.—The remaining tests to be described were made at Lansing, Mich., and on the engines built by the Lansing Iron and Engine Works of that place.

The first engine tested was a new 12 x 18-inch automatic engine. A series of trials to determine change of friction with change of load was first made, which gave us the average friction, 8·91 horse-power, whether loaded or light. Considerable difficulty was experienced in attaching the dynamometer, and it is found impossible to obtain the friction on each distinct part of the engine. For this trial the springs of the dynamometer were flexed in the opposite direction from that adopted when it was calibrated; the results were taken as proportional, and the total made to agree with the previous trial. The highest speed attained was sixty-eight to seventy revolutions; the normal engine speed was in the previous trial 190 revolutions. The friction horse-power in the last column was obtained by multiplying by the proper ratio. In any event the percentage would not change.

Table V exhibits the distribution of resistances obtained in this case.

TABLE V.—Distribution of Friction Log of Dynamometer Trial. Lansing Iron Works, 12" x 18" Automatic.

Rated 100 H. P.

Condition of Engine.	Symbol.	Mean Ordinate.	Reading from Calibration Pounds.	Tension on Engine Belt. Pounds.	Speed of Engine in Revs. per Min.	H. P.	H. P. for 100 Revs. per Min.
Engine in working condition and hot, . .	A	11·3	45·	76·5	68	2·96	8·88
Piston, cross-head and connecting-rod dropped, ...	B	6·7	25·	42·5	68	1·51	4·53
Valve and eccentric also dropped, . . .	C	5·6	19·75	33·5	73	1·40	3·70

Combination of Results.

Parts of Engine.	Algebraic Work.	Arithmetical Work.	Frictional H. P.	Per Cent. of Total Friction.	Per Cent. of Power of Engine.
Main journals, ...	C	3·70	3·70	41·6	3·7
Valve and valve-gear, including eccentric, ...	B — C	4·53 — 3·70	·83	9·3	0·83
Piston, cross-head, crank and wrist-pins, ...	A — B	8·88 — 4·53	4·35	49·1	4·35
Total, ...	. . .	. . .	8 88	100·0	8 88

The letters used under head of algebraic work stand for conditions shown in the other table.

Distribution of Friction, 7" × 10" Engine—Locomotive Valve-Gear.—The test was conducted in the same manner as the original Sibley College test, except that the power was supplied by a similar engine, and the dynamometer was located between the two. The engine was a traction engine used in thrashing grain; it had a common slide-valve link and two eccentrics. It had been previously tested to find variation of friction with change of load. During the test the engine was taken to pieces in a thorough manner, as originally planned, and the results are in each case satisfactory. In the attempt to run with the connecting-rod disconnected from the cross-head, a machinist held the free end of the rod. A speed of 206 revolutions, however, caused him to exert some force, so that this result is unreliable, as the test shows the same friction as with the main journals alone. The friction on the main journals was measured with the usual fly-wheel, which weighed 320 pounds, and with one that weighed seventy pounds, to note variation in journal friction.

Table VI shows the method of variation of friction resistances in this case, as the engine was gradually dismantled; and Table VII exhibits its distribution among the several elements of the machine.

TABLE VI.—Distribution of Friction.

Traction Engine—Locomotive Type.

7 × 10. Lansing Iron Works.

Condition of Engine.	Symbol of Condition.	Revolutions of Engine.	Mean Ordinate.	Tension on Dynamometer Belt in Pounds.	Friction H. P. at given Speed.	Friction H. P. 200 Revolutions.
Complete, hot, cocks open,	A	196	5·35	19·50	1·47	1·50
Complete, hot, back head off,	B	202	5·68	20·25	1·58	1·56
Piston and rod out,	C	202	4·36	14·75	1·14	1·13
Rod in, spider on, but piston-rings out,	D	200	5·14	18·00	1·40	1·40
Condition C, with 40 pounds steam on valve,	E	198	5·4	19·50	1·49	1·51
Valve and valve-rod off,	F	190	4·3	14·25	1·05	1·10
Remainder of valve-gear off,	G	203	3·6	12·00	0·94	0·93
Condition G, with governor off,	H	203	3·65	12·25	0·96	0·94
Cross-head and pin off (connecting-rod held by attendant),	I	206	3·1	9·00	0·71	0·69
Main journals, standard fly-wheel, weight 320 pounds,	J	200	3·0	8·75	0·67	0·67
		190	3·1	9·00	0·66	0·69
Main journals, small fly-wheel, weight 70 lbs.,	K	262	2·3	5·75	0·57	0·44

TABLE VII.—Distribution of Friction.

7 × 10 *Engine.*

Combination of Results.—Rated 20 H. P.

Parts of Engine causing Friction.	Combination.		Fractional Horse-Power.	Per Cent. of Total Friction.	Per Cent. of Rated Power of Engine.
	Algebraic Work.	Arithmetical Result.			
Main journals,	J	0·68	0·680	35·2	3·4
Crank-pin, wrist-pin, and cross head,	$\frac{H+G}{2} - J$	$\frac{·94 + ·93}{2} - ·68$	0·255	13·1	1·3
Eccentrics and links,	$F - \frac{G+H}{2}$	0·165	0·165	8·2	0·82
Slide-valve and rod, no lead,	C − F	1·13 − 1·10	0·030	1·5	0·01
Effect of 40 pounds of steam,	E − C	1·51 − 1·13	0·380	19·5	0·19
Piston and piston-rod,	D − C	1·40 − 1·13	0·270	16·0	0·135
Piston-rings,	$\frac{A+B}{2} - D$	0·130	0·130	6·5	0·065
Total,	...	...	1·910	100·0	9·52

Note.—In the column headed algebraic work, the letters refer to conditions as denoted in preceding table.

DISTRIBUTION OF FRICTION.

Engine, Condenser and Air-Pump.—Diameter twenty-one inches, stroke twenty inches. This engine, 21 x 20 inches, in connection with an engine 12 x 10 inches, made a compound condensing engine which drove the Thomson-Houston dynamos, used for the electric lighting of the city of Lansing. A complete test for friction, with change of load had previously been made of these engines, separately and combined. This engine being larger than could be driven by power transmitted through the dynamometer, the plan was adopted of utilizing the connecting-shaft between the high- and low-pressure engine, and of measuring the power necessary by indicator-cards on the high-pressure engine. Metallic paper, and a fine brass point was used instead of the usual paper and pencil employed in taking indicator-cards. Two dynamos were allowed to run light during the whole of this test, being driven by the high-pressure engine; this friction being eliminated in the final result.

The method adopted was to take indicator-cards of the high-pressure engine, and the load to be carried throughout the test; then to add successively the main journals in the engine to be tested, the condenser and air-pump, the connecting-rod and cross-heads, the valve and valve-rod, and finally the piston and piston-rod.

The plan was in great part successful, but could not be entirely carried out.*

Table VIII shows the distribution of the friction in this series of trials.

There were several conditions during this test that were not uniform throughout; nor were they normal. For instance, in cases *C*, *D* and *E* cards 7 to 15, the valve or piston of the engine or both was in motion, and it was

*A serious accident was barely escaped after the air-pump had been attached and while the connecting-rod was detached from the crank-pin. The vacuum caused by the working of the air-pump, drew the connecting-rod toward the rapidly revolving crank; the meeting of the two was heralded by a sudden and violent pounding. The rapidity of the motion prevented any serious damage, until the connecting-rod could be safely put out of the way.

impossible to lubricate the valve, although the piston was lubricated without difficulty. The results in both cases, *C* and *D*, can be considered as relative only, not absolute. Again, in case *E*, it was found impossible to prevent the

TABLE VIII.—Distribution of Friction.

Condensing Engine.

21″ × 20″ built by Lansing Iron and Engine Works.

Condition of Engine.	Symbol of Condition.	No. of Card.	Revolutions per Minute.	Head Indicator. M. E. P.	Head Indicator. F. H. P.	Crank Indicator. M. E. P.	Crank Indicator. F. H. P.	Total Friction. H. P.	Average Friction. H. P.
High-pressure engine and fixed load.	A	1	207	4·5	14·36	5·0	15·32	29·88	28·9
	A	2	207	4·5	14·36	4·0	12·42	26·78	
	A	3	207	4·75	15·16	4·75	14·74	29·90	
Main bearings of 20 × 24 engine coupled on.	B	4	205	4·5	14·23	6·25	19·21	33·44	35·2
	B	5	205	4·5	14·23	5·75	17·67	31·99	
	B	6	203	4·75	15·02	5·75	16·13	31·15	
Valve and valve-rods connected to eccentrics.	C	7	204	4·75	18·56	7·5	28·50	47·06	42·5
	C	8	202	5·0	19·35	5·5	19·70	39·50	
	C	9	200	5·0	19·16	6·	22·36	41·52	
Air-pump and condenser added.	D	10	198	5·0	19·27	8·5	31·35	50·62	48·6
	D	11	200	5·3	20·31	7·3	27·47	47·98	
	D	12	192	5·0	22·07	7·	25·04	47·11	
Connecting-rod with cross-head and piston added.	E	13	200	13·5	52·73	14·15	54·96	107·69	113·88
Air-pump gauge with pressure as shown subsequently.	E	14	172	17·5	57·68	18·5	59·28	116·96	
	E	15	172	18·	57·68	18·	59·32	117·00	
Average work shown by vacuum-gauge.	F	..	.....	.....	.....	.....	.....	.....	63·80

action of the air-pump on the piston; the work done was, however, shown by the vacuum-gauge, and was equivalent, respectively, to a pressure of 9·82, 10·3 and 10·3 pounds, in cards 13, 14 and 15, or a work equivalent to 69·26, 61·12 and 61·12, with an average of 63·8 horse-power, over and above that due to moving the engine. The average of a large number of previous trials gave 7·13 horse-power as the total friction of this engine together with air-pump and condenser; and this fact must be noted in considering cases *C* and *D*.

Combining these various observations, we get the following results: Friction on main journals equals

$$B - A = 3{\cdot}3 \text{ H. P.}$$

Engine complete, air-pump at work, case *E*, gives 113·88 horse-power; without piston, air-pump and unlubricated valves as before, gives us case *D*, 48·60 horse-power. The difference, 65·28 horse-power, includes work of air-pump and friction of piston and rod. The work of air-pump is 63·8 horse-power, leaving for friction of piston and rod 1·48 horse-power.

The difference between the total friction, and that on the parts, already found, is the sum of the friction for cases *C* and *D*, which must be divided in the proportion indicated by the observations. Table IX is a summary of the deductions from this set of trials of a condensing engine.

TABLE IX.—Distribution of Friction.

Condensing Engine, 21" × 20".

Summary of Results.

Parts of Engine Considered.	Conditions Combined Algebraically.	Friction. Horse-Power.	Per Cent. of total friction.
Main journals,	B — A	3·3	46·
Piston and rod, cross-head and pins,	E — (D + F)	1·48	21·
Valve-rod and eccentric,	Determined as explained	1·47	21·
Air-pump and condenser,	" " "	0·88	12·
Total,	. . .	7·13	10·

COËFFICIENT OF FRICTION.

The coëfficient of friction can be deduced with certainty only for the main journals of the engine; since there is a variation in pressure of piston-rings, stuffing-boxes, and in angularity of the connecting-rod, which is, at least to a great extent, unknown.

If we call *f* the coëfficient of friction, *p* the pressure on the bearings in pounds for engines light, and plus mean pressure on piston for engines loaded, *c* the circumference of the bearings in feet, *n* the number of revolutions per

minute, $f\ p\ c\ n$ will thus equal the "lost work" of friction; which has been determined in the previous experiments,

TABLE X.—Coefficient of Friction for the Main Bearings of Steam Engines.

Engine.	F. H. P. due to Main Journals.	Weight on Journals in Pounds.	Diameter of Journal in Inches.	Coefficient of Friction, Engine Light.	Coefficient of Friction, Engine Loaded.	Revolutions of Journal per Minute.
6" × 12" Straight line, ...	0·85	1,500	3	·10	·06	230
*12" × 18" Automatic (L. I. W.), ...	3·70	2,600	5	·19	·05	190
7" × 10" Traction (L. I. W.), ...	0·68	500	2¾	·31	·08	200
21" × 20" Condensing (L. I. W.), ...	3·30	4,000	5½	·09	·09	206

* The 12" × 18" automatic engine was new, and gave, throughout, an excessive amount of friction as compared with the older engines of the same class and make.

TABLE XI.—Distribution of Friction.

Summary of Results.

Parts of Engine.	Percentages of Total Friction.				
	Straight Line 6" × 12" Balanced Valve.	Straight Line 6" × 12" Unbalanced Valve.	7" × 10" Lansing Iron Works—Traction Locomotive Valve-Gear.	12" × 18" Lansing Iron Works—Automatic Balanced Valve.	21" × 20" Lansing Iron Works—Condensing Balanced Valve.
Main bearings, ...	47·0	35·4	35·0	41·6	46·0
Piston and rod, ...	32·9	25·0	21·0	49·1	21·8
Crank-pin, ...	6·8	5·1	13·0		
Cross-head and wrist-pin, ...	5·4	4·1			
Valve and rod, ...	2·5	26·4	22·0	9·3	21·0
Eccentric-strap, ...	5·3	4·0			
Link and eccentric, ...	. . .	. . .	9·01	. . .	. . .
Air-pump, ...	. . .	. . .	. . .	. . .	12·0
Total, ...	100·0	100·0	100·0	100·0	100·0

and is expressed as horse-power; this is indicated to foot-pounds by multiplying by 33,000.

Hence,

$$f\,c\,p\,n = 33{,}000 \text{ H. P.}$$

$$f = \frac{33{,}000 \text{ H. P.}}{p.\ c.\ n.}$$

Table X shows the value of this coëfficient for the several engines tested, and Table XI is a summary of *all* results.

CONCLUSIONS AND DEDUCTIONS.

In each case the engine to be experimented with was first examined, by the process which has been so fully described in the preceding papers on this subject, to determine whether its friction under varying loads was actually constant, as in the engines previously tested. This was found to be practically the case in every instance, and even the compound engine, contrary to the expectation of the writer, exhibited substantially the same internal friction at all loads up to its full rated power, and with no load at all. The minimum friction was 13·5 horse-power, the maximum 17·5, varying irregularly, with the character of the lubrication, probably, and giving the higher or the lower figure indifferently whatever the work done, and however the power might be distributed between the two cylinders. As this engine was non-condensing, the problem still remains to be solved with respect to condensing engines, unless, indeed, the few experiments thus far reported may be taken, as is very probably the fact, as indicating the truth of the general principle of constancy of internal friction for all engines, whether condensing or non-condensing.

These engines were also all tested to determine whether the previously reported increase of internal friction with speed were here to be accepted as correct. It was found that the several engines differed somewhat in this respect, but that the variation was in all cases slight, and in some instances insensible or even reversed, the friction decreasing in one case, observably, with increasing speed. It was sufficiently evident, for all the engines here considered, that this variation was so unimportant as to be negligible. The

figures given in the several tables which have been presented in the preceding pages are therefore to be accepted as not only correct and reliable, but also as not likely to be affected by construction or method of operation of engine to such an extent as to be inapplicable to steam engines generally. The writer, in the light of existing knowledge, would assume that it is the rule, with all the usual forms of engine, and under all common conditions of operation, that the internal friction of the machine is practically invariable with variation of useful work, and that it is very nearly independent of the speed of rotation and of piston, varying slightly, as a general rule, in the direction of increase with increase of speed. This latter principle leads to the conclusion that the friction coëfficient of the rubbing surfaces decreases with the load on the engine and with increase of pressure on them, a result confirmed by numberless experiments of the writer and others, independently. With good lubrication, the coëfficient of friction rapidly decreases with intensifying pressures, and to such an extent as to make the actual resistance to movement very nearly constant. It is now possible to study the reported data intelligently, and to deduce useful and reliable conclusions relative to the effect of these new facts upon the theory and upon the principles of designing and constructing as well as operating steam machinery.

The last table presented, summarizing the work of the whole research, gives in most readable and intelligible form the data and the laws which it has revealed. The most important item of friction waste, in every instance, is that of lost energy at the main bearings. In every case it amounts to one-third or one-half of all the friction resistance of the engine, the higher figures being given by the condensing, the lower by the non-condensing engines, except that the first experiment, with the straight line engine, gives as high a figure as the condensing engines, a fact due, however, rather to the exceptionally low total than to exceptionally high friction on the main shaft. The second highest item is, in all cases apparently, the friction of piston and rod, the rubbing of rings and the friction of the rod pack-

ing. This is a very irregular item, as would naturally have been anticipated, and amounts to from a minimum of twenty per cent. to some higher but undetermined quantity. The third item, in order of importance, is the friction of valve, in the case of the engines having unbalanced valves. This is seen to be hardly a less serious amount than the frictions of shaft and of piston. But it is further seen, at once, that this is an item which may be reduced to a very small amount by good design, as is evidenced by the fact that, in the straight line engine, it has been brought down from twenty-six to 2·5 per cent. by skilful balancing. Ninety per cent., therefore, of the friction of the unbalanced valve is avoidable or remediable. The importance of this fact is readily perceived when it is considered that not only is it a serious direction of lost work and wasted power and fuel, but that the ease of working of the valve is a matter of supreme importance to the effective operation of the governing mechanism in this class of engines. No automatic engine can govern satisfactorily when the valve is unbalanced, and is certain to throw much load on the governor. The frictions of crank-pin, of cross-head, and of eccentrics, are the minor items of this account; they are comparatively unimportant.

Studying these facts with a view to further improvement of the steam engine, certain inferences are at once obvious. The improvement of the steam engine has to-day reached a point beyond which, in its thermodynamic relations, but little advance can be anticipated. Under usual conditions of operation of our very best engines, they are so near the efficiency of the ideal engine, working under precisely similar conditions, that the range of possible gain left to us is too small to permit us to look in that direction for rapid or important changes in further increase of efficiency and economy. Where the ideal engine would consume ten pounds of steam per horse-power per hour, we have actually reached as little as fourteen, if the latest and best reports of the best of modern engines may be accepted as substantially correct; and even this thirty per cent. margin is reduced by practical conditions restricting expansion. If it

were to be asserted that we may hope to bring the consumption of steam in good engines of the best type down to as low as twelve pounds per hour per horse-power, it is probable that the most experienced and best informed engineers would think it a somewhat rash statement; but, in the opinion of the writer, that is what the tendency and rate of recent improvements would seem to promise for the immediate future, assuming that no very great increase in pressures and temperatures of steam may be expected. Practically, also, it is now known that the highest duty is not the most desirable, nor, on the whole, the most advantageous condition of operation of the engine, and we are restricted to lower duties and reduced efficiencies whenever we consider financial relations. It is, nevertheless, the fact, that the conditions of improvement are those which also give higher ratios of expansion for the best point of cut-off and most advantageous ratios of expansion. The duty to seek further means of improvement and higher efficiency becomes all the more imperative when we study the practical conditions under which our engines must be employed. Having, however, as just remarked, so nearly reached the limit of possible gain on the thermodynamic side, it becomes advisable to seek the more carefully for opportunities of improvement in other directions. We have, in the work outlined in this paper, both the directions shown us and the specific method of procedure suggested.

The real, final efficiency of the steam engine, or of any heat engine, as has been somewhat fully shown in earlier papers by the writer,* and later by others, is composed of the resultant of several distinct efficiencies, as the thermodynamic efficiency, the efficiency of the engine as a heat preserver and user, the efficiency as a machine, and the efficiency of a whole considered from a commercial standpoint. Of these several efficiencies, we have in this investigation the means of studying the efficiency of the machine as a division of the whole within which to seek the best

* "On the Several Efficiencies of the Steam Engine." *Trans. Am. Soc. M. E.*, Vol. viii, p. 86.

means of securing a gain of total efficiency. The real and final efficiency is certain to be increased if we can effect an improvement at this point, whatever the extraneous conditions of operation. Finding little chance of gain thermodynamically, it becomes our duty to ascertain what are the probabilities of securing progress elsewhere. It is at once seen that the difference here between the real and the ideal engine is greater than in the domain of thermodynamics, the best cases being in both instances taken. Those engines which are most nearly perfect thermodynamically, are undoubtedly often least perfect, or at least of the least perfect types, when the efficiency of the engine as a machine is studied. Few of them have less than a total of twenty per cent. friction; while they are sometimes probably nearer the ultimate limit of improvement, practically, as converters of heat into work. We are now, for the first time in the history of the theory of the steam engine, in a position to say just where the losses of the machine are in detail, how we are to endeavor to reduce them, in what degree we may hope for such gain, and where it is to be found if effected at all.

The first and most remarkable fact to be noted is the extraordinary amount, absolutely and relatively, of the friction of the crank-shaft. This amounts to nearly one-half of the whole waste, and to from five to ten per cent. of the whole power of the engine, in the cases here examined. It is remarkable not only for its amount, but also because of the fact that we had begun to believe that, under similar conditions of pressure, speed of rubbing, and of lubrication, it was perfectly practicable to bring down the coëfficient to less than one per cent. and perhaps to as little as one-tenth of one per cent. Here, however, we find, on examination of Table X, that this coëfficient rises, in the unloaded engine, to about 0·30 as a maximum, and, as a minimum, to at least 0·09; while it only falls to 0·04 in the best case, with the increase of pressure on the bearings due to full load and power. This is the more astonishing when it is considered that, on the axle of the car-wheel, it has been found often that the friction is a fraction of one per cent. and often as low as

one-tenth per cent. Here is evidently the first place in which to seek further improvement. If this item can be brought down as low as in car-axle journals, the efficiency of the engine as a machine will be increased by about five per cent. in the very best cases, and by ten per cent. in ordinary engines. How this is to be done can be best ascertained when it is found just what are the causes of this extra-ordinary and previously unsuspected loss. The only conditions apparent tending to exaggerate this waste are the continuous rotation in one direction and the unintermitted pressure of the journal in its bearing. It would appear probable that it is a case of commonly imperfect lubrication. Could the oil-bath system in method and in results be secured here, it would seem probable that the friction might be enormously reduced. It would even in many cases, if not in all, pay well to have a thoroughly reliable system of lubrication by means of a forcing pump that should insure the support of the journal upon a cushion of lubricant, thus making its action analogous to that of the "*palier glissant*" of Giffard and the "water bearing" of Shaw and of others.

The second and most obvious conclusion is that the valve should be balanced and so connected as to cause the least possible waste by friction through its motion or that of its moving connections. There is evidently no probable line of improvement so certain to yield a large and profitable result as this. The balancing of the valve has been accomplished, and frequently, during many years past, and so successfully that there is no excuse for neglecting this point in even the cheapest classes of engines. No engine can be considered as belonging to the best class which is not either provided with a balanced valve or which has not a system of valve-gear as with some of the "drop cut-off" engines, in which the loss in this direction is rendered insignificant. Here lies an opportunity to raise the efficiency of mechanism of ordinary engines at least five per cent., and of the best of engines with unbalanced valves two or three per cent. It is evidently better, in many cases, to have a valve which is balanced, though slightly leaky at times, than to use an unbalanced valve, though absolutely tight at

all times. The simple fact, here revealed, that nine-tenths of this friction may be avoided is very important.

The third item in order of importance is the friction of piston and its rod. This is as great as that just referred to, and is vastly more variable with the class of engine, and probably in the same engine with differences in handling, and especially in setting up packing and springs, where they exist. The writer has often known the power of an engine to be sensibly affected by the carelessness or inexperience of the attendant, who had screwed up his packing in the rod stuffing-box too tightly, and has, on more than one occasion, had a similar experience where the rings were set out too hard. The metallic packings and the unpacked pistons and rods now coming slowly into use will unquestionably do much to remedy this defect of the average engine. Meantime, with the older design, it is perfectly possible to keep piston and stuffing-box tight without wasting much power, or by slowing down the engine by conversion of heat into work at points where the operation is likely to produce serious harm as well as waste. Rings are much oftener too tight than too loose, and a stuffing-box should only be set up when the engine is running, and then only with fresh packing and not more than is sufficient to check any visible leakage. New packing in a well-made box never needs much compression and when it becomes necessary to screw it down hard, it is time to replace it by new. Any packing that compels severe compression when new should be promptly condemned.

The remaining items are of minor importance as bearing upon the efficiency of the machine, and they are all obviously easily taken care of by a good designer and a good engineer in charge. Here, if anywhere, it is the fact that freedom of lubrication is the essential consideration, and the more nearly absolutely flooded the parts can be, and the more absolutely certain lubrication can be made, the better, and irrespective, also, to a great extent, of the cost of the lubricant. Any lubricant freely used can be filtered and cleansed in such manner and so effectively, that its more or less free supply to the bearing is a matter of no

consequence as a matter of first cost, while the cost of wasted power and fuel, and of repairs due to excessive friction and wear, will usually enormously exceed any apparent gain in that direction. This latter consideration has been very fully treated by the author elsewhere,* and is probably also too familiar to engineers of experience to make it advisable to extend the limits of this paper so as to include more of detail in this and other matters. The importance of the work of which this is the history is sufficient, however, probably, to justify the length to which the paper has already extended.

By reducing the several items of waste and loss above enumerated to their minimum amounts, in the various ways pointed out, and by other less obvious expedients, it is evident that the efficiency of the machine may be so far advanced, in the case of the ordinary engine, as to give us the power of applying from five to ten per cent. of the total indicated power of the engine to useful, instead of to wasteful purposes, and thus to effect a gain of no small amount by improving both sides of the account.

Messrs. Carpenter and Preston have done other work of value, to which it may be possible to give attention later, and Prof. Carpenter is independently pursuing the study of the internal friction of engines. It is hoped that we may, in time, secure a very large body of valuable data, and especially that we may, after a time, be able to indicate the laws of its distribution with some accuracy for all types and styles of engine in common use.

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* *Friction and Lost Work in Machinery and Mill-Work.* J. Wiley & Sons: New York. 1885.

ELECTRIC WELDING.

[*Abstract of remarks made by Prof. Elihu Thomson, on showing his electric welding apparatus in operation, at the stated meeting of the* FRANKLIN INSTITUTE, *held September 19, 1888.*]

JOS. M. WILSON, President, in the Chair.

Prof. THOMSON spoke substantially as follows:

About a year and a half ago I gave a description of the newly-developed art of electric welding, calling attention to the principles underlying its practice and the results accomplished in the welding of various metals and alloys.

On the present occasion, the purpose is to show the apparatus, or at least a few forms of it, in operation, and to describe the working and construction.

Quite a number of types of apparatus have been developed, some of which are before us, and others we have at our factory at Lynn, Mass.

What we call the indirect, or induction, type takes current of comparatively high potential from a dynamo giving alternating currents, or from any other suitable source, such as a lighting supply line, and converts, or induces, from it a current of very low potential and great volume for electric welding, soldering, brazing and forming of metals. One form of apparatus, which will be used for welding iron and copper wires, is here before you (*Fig. 1*).

The "direct" type generates the currents needed directly from belt power or mechanical energy, and consists of a specially organized dynamo provided with a set of welding clamps. In fact, the needs of electric welding have given rise to a number of special and somewhat curious types of dynamos, which might not otherwise ever have been invented or constructed. But one of these forms is here shown, a number of others having been designed and constructed, and others again are undergoing construction. *Fig. 2* is an example of a type of direct-welding dynamo,

similar to the one on the platform, belted to the INSTITUTE engine.

The storage battery, properly arranged, constitutes another type. It is charged from a line, or by a small dynamo kept running constantly by power. Since the welding or heavy-discharge currents are only needed at intervals, a comparatively small dynamo will usually suffice for the charging. We have used a suitable cell of storage battery quite successfully in electric welding. Even primary batteries may, if of sufficiently low internal resistance, be used for the work, but are comparatively expensive to run.

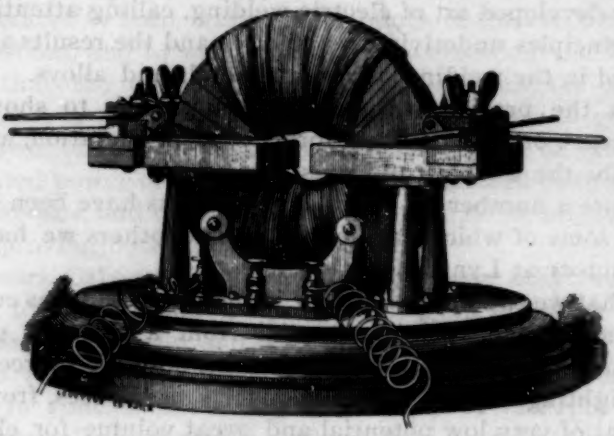

FIG. 1.

Variations in the proportion and details, especially of the clamping devices, are made to suit the nature and size of the work to be done, and the shape of the pieces to be handled.

It may be mentioned that for some purposes a combined engine and dynamo for welding may come into use, especially where the work is intermittent. Thus an apparatus in all respects like a steam fire engine, but with a dynamo generating the requisite currents and substituted for the pumps, would be useful where portability is requisite and comparatively heavy work is to be done in isolated localities. The fact that the work is intermittent permits the use of less

boiler capacity than would be the case were the plant to be under full load continuously.

(At this point a number of lantern slides were shown on the screen. They represented some of the various forms of apparatus which have been constructed, and their differences were pointed out.)

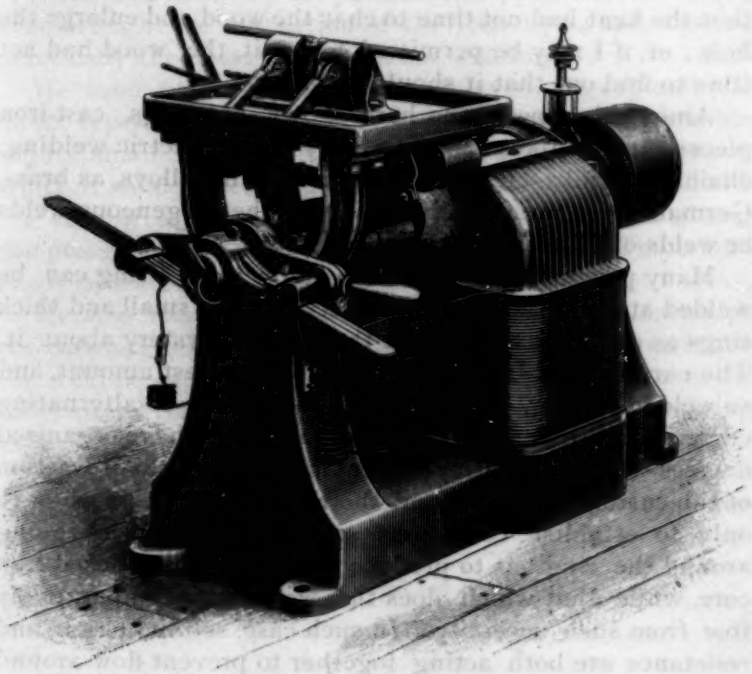

FIG. 2.

Prof. THOMSON continued:

I call attention to the numerous examples of work done as exhibited by the specimens which are found on the two sample boards before you, and upon the table. Here is a unique specimen, a shaft with two collars, formed without any welding at all, by simply pressing it endwise by the clamps with the current put on.

Here, again, is a very curious piece, which I am sure could not be produced at all without such apparatus as is

shown here. It demonstrates the rapidity with which work can be done, and the localization of the heating effects.

The specimen referred to is one in which a bar has been put through a hole in a flat piece of wood, and burrs raised on the bar at both sides of the wood, so that the wood is held between the two expansions in the bar, and almost pinched between them. The operation was so quickly done that the heat had not time to char the wood and enlarge the hole; or, if I may be permitted to say it, the wood had not time to find out that it should burn.

Among the specimens here shown are rings, cast-iron pieces, various tools constructed by use of electric welding, chains and links, etc. The various metallic alloys, as brass, German-silver, are seen, in addition to heterogeneous welds or welds of different metals one to the other.

Many persons are puzzled to know how a ring can be welded at all by the current, especially such small and thick rings as are here shown, but there is no mystery about it. The current goes by the short path in greatest amount, and so welds the ring. This is particularly true of alternating currents of rather rapid rate, and, in fact, we have organized devices which absolutely prevent more than a small fraction of the current going around the ring. To do this we have only to establish conditions such that a current going around the ring has to produce magnetism in a closed iron core, while that which does the welding is comparatively free from such necessity. In such case, self-induction, and resistance are both acting together to prevent flow around the ring, instead of across the joint to be made.

Tests of tensile strength of electric welds are eminently satisfactory, and the occasion may sometime come when I can present the results, or consider for you electric welding from the standpoint of its perfection as a welding process. Its utility is, however, already established. It does very many things which no other process can do or has done.

Here is a sample of lead pipe welded without obstruction of its interior, and even without expansion outside. At a short distance away, the pipe cannot be distinguished from a plain piece, and its exterior has been left just as it came out of the welding clamps.

Here again, is a finished axe, with the steel cutting edge welded to the body by electrical means, the welding being the last operation done before final grinding for finish.

Here is a steel rake made by electricity, and several specimens illustrating the making of carpenter's squares by electric welding.

(Prof. THOMSON then explained the apparatus, which had been brought for inspection of the INSTITUTE, and showed practically the operation of electric welding.

He used both the induction coil type (*Fig. 1*), and the direct types (*Fig. 2*). Some of the apparatus was remarkable for its small size in relation to the size of the pieces upon which it would successfully operate. The devices for holding the pieces in place, putting on the current and giving the pressure to the pieces were shown to be very simple and easily operated.

He also exhibited some automatic apparatus, in which the pressure given is automatic, and the current stops when the weld is completed, thus enabling the operation to be indefinitely repeated in the same way without involving skill on the part of the operator.

At the close of Prof. THOMSON'S remarks, a vote of thanks was tendered to the speaker for his extremely interesting presentation of the subject.)

MEMOIR OF THOMAS USTICK WALTER, LL.D.

BY GEORGE C. MASON, JR.

THOMAS USTICK WALTER, LL.D., second President of the American Institute of Architects, was born in the city of Philadelphia, September 4, 1804, and died in the same city, October 30, 1887, being, at the time of his decease, the oldest practising architect in the United States. He was a son of Joseph S. and Deborah Walter, and was named after the Rev. Thomas Ustick, a well-known divine during the early years of the present century.

In boyhood Dr. WALTER displayed a predilection for mathematics. His education was liberal, but not scholastic. In 1819, being then fifteen years of age, he entered the office of William Strickland, the architect of the Mint and Custom-House. From his own writings it is learned that he remained with Strickland until he had acquired the art of linear drawing and a general knowledge of the profession of architecture, after which he resumed his general studies and subsequently went through an elaborate course of mathematics. For seven years he devoted himself to the study of physical sciences, to the cultivation of the arts of drawing and painting, and to the attainment of practical knowledge of the several branches of mechanical construction; at the same time he studied landscape painting in water-colors with Mason, a celebrated teacher of that art. In 1828, he again entered Strickland's office, devoting himself exclusively to architectural study, the practice of which he commenced in 1830. In 1831 he designed the "Philadelphia County Prison." This was his first important work; his plans being adopted and he formally appointed architect October 14, 1831.

At a meeting of the FRANKLIN INSTITUTE, held September 10, 1829, he was elected to membership, being proposed by Mr. S. V. Merrick. On January 14, 1830, he was elected one of the Board of Managers. Dr. WALTER'S

interest in the FRANKLIN INSTITUTE was active from the first and he entered heartily into its counsels and discussions. Even at this early date, when the public taste for correct architecture was wholly undeveloped, he worked and argued for the advancement of his art. This enthusiasm bore fruit. July 16, 1835, it was voted, "That a course of lectures on architecture delivered annually before this Society is indispensable as well to accomplish the ends as to promote the prosperity of the FRANKLIN INSTITUTE, and that it is hereby warmly recommended to the Board of Managers to secure the delivery of such a course next winter."

The times were not altogether propitious for the establishment of a regular professorship; but on January 3, 1836, Dr. WALTER was requested to deliver "voluntary lectures." These lectures he continued to give from time to time and on April 1, 1839, he was again requested to "lecture on architecture during the following winter," and thenceforth his name appears on the JOURNAL as "Professor of Architecture."

Dr. WALTER, during these early years of his practice, and his connection with the FRANKLIN INSTITUTE, frequently contributed to its JOURNAL. He fully appreciated the dignity of his art, and from the first his pen and his public utterances were all to one end—its elevation and the cultivation of high aspirations among its practitioners. Thus, in 1841, he writes: "If architects would oftener aim to *think*, as the Greeks thought, than to *do*, as the Greeks did, our columnar architecture would possess a higher degree of originality, and its character and expression would gradually become conformed to the local circumstances of the country and the republican spirit of its institutions."

Among the articles, which, from time to time, he contributed to the JOURNAL during these years, may be enumerated the following titles:

"Architecture in the Middle Ages."

"Formation of an Artificial Spectrum."

General articles under the head "Architecture."

"Orders of Architecture."

Elaborate reports and descriptions of the design and construction of the County Prison and Girard College, then in course of erection, besides numerous other articles.

On January 21, 1846, Dr. WALTER was elected Chairman of the Board of Managers, and held the office for one year.

Dr. WALTER'S professional practice rapidly increased. His design for "Girard College for Orphans" was adopted by Councils in 1833, and the corner-stone laid on July 4th, of that year. This work was completed in 1847. He was then elected one of the Board of Directors of the College, serving for three years.

In 1838, the Building Committee of the College sent Dr. WALTER to Europe for the purpose of "examining the practical workings of the various devices and appointments for health, convenience and comfort, in the principal seats of learning in Great Britain, and on the Continent, with a view to derive such information on these subjects as would be likely to prove useful in fitting up and furnishing the building of the College."

We must now recall an event which may be said to have been the beginning of all architectural development and systematic and united methods of architectural practice in the United States, viz: the attempt, in 1836, to found an "American Institution of Architects."

At that time there were only about a half score of properly trained architects in the country. These gentlemen met in the city of New York, December 7, 1836. Dr. WALTER was one of the pioneers of the movement, and of the group of architects who met on that day, one alone remains—Alexander J. Davis, the architect of the "University of the City of New York." A draft of a constitution was formulated, and the meeting adjourned to meet in Philadelphia on the first Tuesday of May, 1837. The circular calling for this meeting, dated March 23, 1837, was signed by THOMAS U. WALTER, Secretary, and the meeting was held at the Pennsylvania Academy of the Fine Arts, in Philadelphia.

The "Institution" did not last. It embraced but a handful of members, and those too much scattered for mutual

sustenance and the strength necessary for a brotherhood. It struggled for awhile, flickered and went out.

In 1843, Dr. WALTER was invited by the government of Venezuela to visit La Guayra, with a view to the construction of a mole or breakwater. His designs and estimates were approved, and on the 12th of October, 1843, he entered into a contract for the erection of the work. On October 24, 1845, the breakwater was finished and accepted by the government. He then returned to Philadelphia and resumed his general practice.

In 1849, Madison University, New York, bestowed upon Dr. WALTER the honorary degree of Master of Arts.

Dr. WALTER'S position was now assured. He had designed and executed noble works, well and honestly constructed, and designed in the pure classical style of which he was the most strenuous advocate and enthusiastic student. Among his works of private practice may be enumerated St. George's Hall, the Preston Retreat and the Biddle and Cowperthwaite places on the Delaware River.

But all these creditable works, and the struggles of his early years, were but the training and leading up to, as it were, the one great work with which his name must ever be associated, the extension of the Capitol at Washington, D. C., together with the noble dome which surmounts and dignifies its mass.

On the 11th of June, 1851, Dr. WALTER was appointed architect of the Capitol extension in the following letter:

To THOMAS U. WALTER, ESQ.:

SIR: You are hereby appointed architect to execute the plan adopted for the extension of the Capitol as authorized by the Act of Congress, approved 30th September, 1850, making appropriations for the civil and diplomatic expenses for the Government for the fiscal year ending 30th June, 1851; your compensation will be determined hereafter. MILLARD FILLMORE.

Washington City, June 11, 1851.

The appointment was well merited. Of all American architects of that time, Dr. WALTER was the best fitted by study and innate love for the purest types of classic architecture to grasp successfully the problem of the Capito extension, and to design the dome with which, later, he glori-

fied and crowned his work. The boldness of his composition evidences his skill as a designer and his confidence in himself. The vast wings forming the extension are of white marble, of great hardness and durability—they have taken upon with years a delicate pearly color, which, as it shows itself in the long colonnades, gives them an effect of purity and beauty. The crowning glory of this edifice is the dome. Much as we pride ourselves upon the advances made in architectural design, we have nothing to show more nobly simple and well studied than this, the grandest of Dr. WALTER'S works. Such is the verdict of the architect and the critic. Fergusson, the historian of architecture, and often a severe censor, writes: "Taking it all in all, however, there are few buildings erected in modern times which possess to a greater extent than the Capitol at Washington appropriateness of purpose combined with the dignity necessary for the Senate house of a great nation. It has not the variety and richness of detail of our Parliament houses, but it is a far statelier building, and its faults are those of the age in which it was commenced, and which have tied the hands of subsequent architects, and prevented them from using the improvements that have since been introduced in the arts of design; but it wants but very little to enable it to attain to very high rank among the buildings of its class in other parts of the world."

The Hon. J. H. B. Latrobe, son of Benjamin H. Latrobe, the architect of the old Capitol at Washington, thus eulogized Dr. WALTER in an address before the American Institute of Architects in the city of Washington, November 16, 1881. Speaking of the extension of the Capitol Mr. Latrobe said: "I can scarcely speak in his presence as I would like to speak, could I find words to do justice to the last architect of the vast pile that now looks down upon the Federal City. The pupil of Strickland, as Strickland was the pupil of my father, it has been with me a pleasing fancy for more than a quarter of a century to believe that there was, in some faint way, a law of descent, applicable under the circumstances, which connected the architect who clothed Thornton's skeleton with sinew and muscle and beauty until the

whole creature became his own, with his brilliant, refined and accomplished successor, who, at the head of a profession, socially, to-day, without a superior, has absorbed all that has been done before in what is now the Capitol; who, making the magnificent dome, on whose iron sheets the hammer never ceased to ring during the war that threatened to make the whole structure worthless, has screened with it all the exterior littleness of a vitiated taste, and made even the incongruities of the Italian Renaissance subserve the purposes of genius."

Ill health compelled Dr. WALTER to resign from the service of the Government, June 1st, 1865, and he then returned to Philadelphia.

Among the important works that Dr. WALTER executed for the Government between 1851 and 1865 may be enumerated:

The extension of the Patent Office;
The repairs to the Congressional Library;
The extension of the Treasury Building;
The general Post-Office extension;
The Government Hospital for the Insane;

all at Washington; and the Marine Barracks, at Brooklyn, N. Y., and at Pensacola, Fla. In 1860 he delivered a course of lectures on Architecture at Columbian College, D. C., and he also delivered lectures on the same subject in Philadelphia and vicinity.

In 1853, the University of Lewisburg, Pa., conferred upon Dr. WALTER the degree of Doctor of Philosophy, and in 1857, Harvard University gave him the degree of Doctor of Laws. He also became a member of the American Philosophical Society.

Dr. WALTER was now well advanced in years and full of honors. After his return from Washington he engaged in but little private practice. When the erection of the new City Hall was commenced he became connected with Mr. John McArthur, Jr., its architect, and continued to assist him on that work until a short time before his death.

Of Dr. WALTER'S connection with the American Institute of Architects the profession may well be proud. The

original "Institution of Architects" had fallen to pieces for want of cohesion. The American Institute was founded in 1857, and on February 23d, of that year, Dr. WALTER was elected a Fellow. On the retirement of its first President, Richard Upjohn, in 1876, he was elected President, which office he filled continuously until his death. His words of counsel and the dignity of his character have done much to enhance the power and influence of the Institute. At his last election to the presidency, December 2d, 1886, he thus expressed his thanks to the Convention; the words are simple and touching and seemed to those who heard them prophetic of the great change to so soon come upon him:

"I return you my thanks, gentlemen, for your kindness, and for your forgiveness. You might have done better all the time; but I began with you almost at the beginning and have been in my place as often as it was possible; and have done the best I could; and I intended, when I came here, to decline a re-election; but my friends have been very kind, and have asked me to agree to it, if I were re-elected, and I have agreed to it for another year. After that, should I live so long, I will ask you to allow me to take a rest. As to the year before us I promise to do all I can for the promotion of the prosperity of our profession, and for the promotion of the interests of our Institute. Everywhere and at all times I am yours, asking you now to look over my imperfections and to enable me to feel still further that I have your sustenance in these matters connected with our profession. I am deeply interested in them and have been so for nearly sixty years. I shall not be troubled that way sixty years longer. Accept my thanks I pray you."

We have thus followed the career of Dr. WALTER from youth to revered old age. His position in American architecture is a proud one. As he modestly puts it himself in the above address: "I began with you almost at the beginning and have done the best I could."

As an architect and scholar, Dr. WALTER'S professional learning was deep and well digested. In style of architectural composition, pure, artistic and dignified. In social

life he was ever the cultured gentleman. In personal appearance, venerable and commanding.

"Truth in art," was the key-note in his professional career; the fundamental law which he laid down for himself and the burden of all his writings and public utterances. "Let us live," he once said, "for the promotion of our art. Let us leave no stone unturned to devise throughout the world the elements of a pure and correct taste."

One more quotation from Dr. WALTER'S addresses to the Institute and I will close this memoir. The last words of his annual address of 1880 speak the whole life of the man. No stronger or more heartfelt words could come from the lips of the Nestor of American architects.

"We owe it to our country, to the age in which we live, to our family, to ourselves, to devote the rapidly fleeting hours of our lives to the accomplishment of the greatest possible good in our vocation; ever seeking to discharge our duties in all good conscience towards those whose interests are intrusted to our care, towards co-workers in the realm of art, and towards Him in whom we live and move and have our being."

BOOK NOTICES.

A MANUAL OF DESCRIPTIVE GEOMETRY, WITH NUMEROUS PROBLEMS. By Clarence A. Waldo, A.M., Professor of Mathematics, Rose Polytechnic Institute, Terre Haute, Ind. Boston: Published by D. C. Heath & Co. 1888.

This handy little volume of seventy-seven greatly condensed pages might perhaps have been more appropriately entitled "A Collection of Exercises in Descriptive Geometry."

The author states, in his preface, his belief that to accomplish the purposes of Descriptive Geometry, "nothing is better than problems of progressive difficulty, which, taken in their logical order, the student can master alone, or with the aid of a small amount of judicious suggestion." Accordingly, a very brief introduction, stating only the broad features of the subject and the author's system of notation, is immediately followed by Part I, forming the major portion of the work and composed "exclusively of problems systematically arranged."

Part II contains "suggestions, analyses and occasional demonstrations," and Part III (very brief) "is a condensed statement designed for occasional

reference in the earlier part of the work, but especially as a review before leaving the subject or in preparing for examination."

Among the special features enumerated by the author is "the omission of all plates except a few of a generic character," but we are not told what advantage is to accrue from this omission.

The work evidences much care in its preparation, and the very thorough drill which its many exercises must give can hardly fail to be of great service to the student. T.

TABLES OF THE PROPERTIES OF SATURATED STEAM AND OTHER VAPORS. By Cecil H. Peabody, B.S. New York: John Wiley & Sons. 1888. 8vo, pp. 3 to 25 text, 1 to 35 XIII tables.

This work contains the result of a set of calculations to determine the pressure, temperature and other properties of saturated steam, founded on the experiments of Regnault, and gives in full the data and methods of calculation. The constants obtained in the general equation—

$$p = a + b\,a^{\alpha} + c\,\beta^{\alpha},$$

representing the relation between the pressure and temperature of saturated steam vary, generally in the thousandths place, slightly from those usually given, making some changes in the tables.

Thus Buel's tables give for

p (pressure) = 15 pounds (absolute),

t (temperature) = 213·067° F.,

while Peabody gives

t = 213·03° F.

For p = 30,

Buel gives

t = 250·293° F.;

Peabody,

t = 250·27° F.

For p = 100,

Buel gives

t = 327·625° F.;

Peabody,

t = 327·58° F.

Rowland's experiments on the mechanical equivalent of heat are given and its value is given as 778 for 45° latitude and at the sea level.

From a combination of Rowland's and Regnault's experiments, the specific heat of water varies for each 5° C., beginning 0° to 5°, in the following order:

1·0072, 1·0044, 1·0016, 1·0000, 0·9984, 0·9948, 0·9954, 0·9982, 1·0000; from 45° to 155° C., 1·008; from 155° to 200° C., 1·046.

Investigation of the formula for the total heat of saturated steam has shown that the one ordinarily used—

$$\text{Total heat} = 606{\cdot}5 + 0{\cdot}305\,t \text{ for French units}$$

represents our best knowledge on the subject.

The results of Tate and Fairbairn's attempts to determine the specific volume of steam by direct experiment, are compared with the results obtained by the thermo-dynamic method, and are shown to be less correct.

The equations expressing the relation between the temperature and the pressure, heat of the liquid, total heat, and the heat equivalent of internal work are given for the vapors of alcohol, ether, chloroform, carbon disulphide, carbon tetrachloride, aceton, sulphur dioxide and ammonia and from them Tables IV to XI are computed.

For saturated steam three tables are given. Table I in English units for every degree Fahrenheit from 32 to 428; II for every pound pressure from 1 to 336; III in French units, for every degree Centigrade from 0 to 220.

Table XII gives the specific gravity, water at 4° C. being the standard, and the specific volumes of the liquids above mentioned, and Table XIII gives the volume of water from 10° to 200° C.

The evident carefulness with which the work has been done, the convenient form in which it is issued, and its containing, as it does, the most recent experiments, will make it the standard reference book for tables of saturated steam. The tables are nicely arranged for use, and could only be improved by putting fifty numbers on a page instead of thirty-nine or forty. H. W. S.

A Few Incidents in the Life of Prof. James P. Espy. By his niece, Mrs. L. M. Morehead. Cincinnati: Robt. Clarke & Co. 1888.

A brief but very interesting memoir with this title has been sent to the Franklin Institute by its author, which is intended primarily to correct some errors that have received currency through careless or sensational writers. It is a grateful duty to welcome this correction, and to join this lady author in a tribute of respect to one of the ablest, most earnest and sincere of all the students of natural science this country has known. He was especially an associate and co-worker with the Franklin Institute, and an active and influential member for many years. Here he began his correspondence with scientific men, both of this country and of Europe, which enlisted universal attention, and received at that time almost universal assent to the theory he propounded. It is certainly remarkable that so much attention should be drawn to the observation of atmospheric phenomena as was done by the lectures, efforts and experiments conducted by Prof. Espy at the Franklin Institute, and where he appealed to the general government for aid to conduct and enlarge his work. He had the name of every man prominent in science in this country to support his applications. He obtained the establishment of a system of meteorological observations in the state of Pennsylvania in 1839, which was before the organization of the Smithsonian Institution, and led to the appointment of Prof. Espy to the position of meteorologist to the Navy Department—not to the War Department, as the author of

this memoir supposes—in 1847. Prof. Espy was, under this appointment, to investigate the theory of storms, to invite the co-operation of private observers, and to report from time to time to the Secretary of the Navy. He did so make three general reports, to the last of which, published in 1851, a large number of folio charts are attached, giving the observations received by him, as taken simultaneously at a large number of stations. These were the proper forerunners of the signal service charts now in use. Prof. Espy's theory of storms has scarcely been sustained by the full course of observations now available for this discussion, and it is found that while several theories have a few storms in each year to represent them, no one form of atmospheric movement is common to them all. It is due to Prof. Espy to say that he often expressed the earnest wish that his researches should stimulate others rather than to be taken as being committed to any theory. He was as liberal in his views as he was energetic in prosecuting them, and contended only for what he saw or fully believed.

The lady who writes this memoir claims no more than is justly due to the memory of the most energetic and conscientious scientist of his time, who sought results by the highest and most comprehensive methods, who directed the use of accurate instruments in making faithful records, the results of which other students of physical science could use as well as himself. He induced the Smithsonian Institution to establish a system of observation, which produced a great body of materials for a climatology. And this was followed first by the Department of Agriculture and next by the Signal Service Bureau.

Mrs. Morehead's memoir is only too brief; it might very well have been more explicit on some points of his personal history, which no biographer has so far given. The absurdities of Perley Poore's pretended reminiscences should be counteracted by an authentic life of this really able and remarkable man, who displayed unprecedented energy in opening up a new field of scientific research. If he did not attain success in verifying his theory of storms, he at least commanded respect and enlisted attention to a degree that had never been equalled at that time.

It is pleasant to read in this brochure of the honorable origin and early associations of Prof. Espy, of his high standing as a student in the University of Kentucky at the time when Perley Poore falsely reports that he "could not read at the age of seventeen," from which University he duly graduated, subsequently studied law, and later became a professional teacher in Philadelphia. The older members of the FRANKLIN INSTITUTE should remember Prof. Espy, who was, perhaps, the most active one among its members for many years, until his removal to Washington about 1851.

Philadelphia, September 27, 1888. LORIN BLODGET.

PREPARING FOR INDICATION; PRACTICAL HINTS. By Robert Grimshaw. New York: Practical Publishing Company. 1888. pp. 56.

This little work, by Mr. Grimshaw, covers the ground suggested by its title completely, and should be in the hands of every one desiring a practical knowledge of the methods of going to work to prepare for taking indicator

cards. The work is divided into chapters, covering the methods of attachment to the cross-head, ceiling or floor, the main lever, the card lever, and the proper place and how to run the piping. Every engineer doing a general consulting business, has felt the necessity of some such set of general directions, which he can send in advance of his going to test an engine and thus save the annoyance and delay of doing this work after he arrives on the ground, and this little book seems to be just what is desired. A few more words in a few places, particularly in referring to the substitute for the slotted lever, might have made the matter clearer, but generally the directions are simple and easily understood, and any one in charge of an engine should be able intelligently to make all the preparation needed from the instructions given. H. W. S.

THE DESIGNING AND CONSTRUCTION OF STORAGE RESERVOIRS. By Arthur Jacob, B.A., late Executive Engineer for Irrigation, H. M. Bombay Service. Revised and extended by E. Sherman Gould, M. Am. Soc. C.E., Consulting Engineer to the Scranton Gas and Water Company. New York: D. Van Nostrand, Publisher, 23 Murray Street and 27 Warren Street. 1888.

Mr. Jacob's well-known little book now appears with some additional remarks by Mr. Gould, who observes, in his brief preface, that "it was considered best, in view of the standard character of the work, to present it in its original form, with all additional matter separate from the text. All of the editorial work, therefore, in the present volume, appears in the shape of footnotes, and the additional pages appended to the original discussion."

The "notes" are few, and generally brief, constituting a running comment upon isolated statements by the author.

The "additional remarks," covering some thirty pages, contain the editor's views as to what constitutes the best practice in this branch. In these, while highly approving the author's work in the main, the editor naturally differs from him in many particulars, chiefly in those where American practice differs from the European. T.

AN ELEMENTARY COURSE IN DESCRIPTIVE GEOMETRY. By Solomon Woolf, A.M., Professor of Descriptive Geometry and Drawing in the College of the City of New York. New York: John Wiley & Sons, 15 Astor Place. 1888.

A most scholarly and conscientious work, both precise and concise (yet ample) in treatment. The language is clear and thoughtful, the arrangement methodical and natural. The work is very thoroughly and beautifully illustrated. The cuts number 289, and most of them are models of clearness. What is of prime importance, they are well *lettered*, apparently being done by the "wax process," which admits of lettering in *type*.

The book is admirably printed on excellent paper, and in the clearest of type. In short, it is, in all respects, a pattern of what a text-book ought to be. T.

SCIENTIFIC NOTES AND COMMENTS.

CHEMISTRY.

AN ELECTRO-CHEMICAL ACTINOMETER.—Gouy and H. Rigollet (*Comptes Rendus*, **106**, 1470). A clean copper plate is heated over a Bunsen burner until the iridescence which first appears is replaced by a uniform tint, the surface then consisting principally of cuprous oxide. The plate may then be preserved from further change by coating with paraffin while still warm. When such a plate is placed with another plate of unoxidized copper in a solution of sodium chloride, an electromotive force of a few hundredths of a volt is developed. On exposure to light, the electro-motive force increases, the oxidized plate becoming more strongly positive. The effect is instantaneous, and ceases as soon as the light is cut off. The variation in the electro-motive force is greater when the circuit has a resistance of several hundred ohms; thus with a Thomson galvanometer a candle flame produces a sensible effect at a distance of several metres. Instead of an oxidized and a clean copper plate, two oxidized plates may be used, only one being exposed to the light. The couple appears to be sensitive to all visible rays.

W. H. G.

DETECTION OF COMMERCIAL SACCHARINE IN ARTICLES OF FOOD.—E. Bornstein (*Zeit. Anal. Chemie*, **27**, 165).—The test is based on an observation of Remsen's, that when a minute quantity of saccharine is heated in a test-tube with a little resorcinol and some strong sulphuric acid, the mixture becomes yellow, then red, and finally deep green, sulphur dioxide being at the same time disengaged with effervescence. On cooling, the solution is diluted with water, and an excess of alkaline hydroxide added: the liquid now appears red by transmitted light, but has a strong green fluorescence. A milligramme of saccharine will yield six litres of fluorescent solution. In applying the test to articles of food, the substance is slightly acidified, preferably with phosphoric acid, and is then extracted with ether, the evaporation of the ether leaving the saccharine sufficiently pure for the reaction. Any fat present is removed with petroleum spirit before the extraction with ether.

W. H. G.

ON THE PURIFICATION OF MERCURY.—J. M. Crafts (*Bul. Soc. Chim.*, **49**, 856,) finds that mercury may be purified in large masses by the simple aspiration of air through it. He places the mercury in a glass tube 5 cm. in diameter and 1·5 m. long, lying on an inclined wooden support. The lower end is closed by a cork through which pass a funnel tube for the introduction of the mercury, and a stop-cock for its removal. The other end is put in communication with a water exhaust pump, and in forty-eight hours all the impurities will be found as a coherent powder in the upper end of the tube, and the mercury can be drawn off practically pure. This powder is too voluminous in the case of mercury that has been used to amalgamate zinc to permit the process to be at once used for such metal. Zinc and lead were

introduced into mercury that had been previously purified by distillation in a vacuum, and, after purification by a current of air, it left no residue when again distilled in a vacuum. W. H. G.

ON THE PROTECTION FROM RUST OF RAILROAD RAILS IN ACTIVE SERVICE.—W. Spring (*Bull. Soc. Chim.*, **50**, 215) believes that the apparent immunity from rust of rails in active service while unused rails soon become thickly covered with rust, is due to the combination, under the pressure of the wheels, of ferric hydrate with the iron of the rail, thus forming magnetic oxide, which protects the iron from further action. This theory is supported by the results of experiments in which thin iron plates were covered with moist ferric hydrate and the mixture subjected to 1,000 atmospheres pressure. The ferric hydrate was blackened and adhered strongly to the plates, which were corroded; the substance next the iron of the plates was found on analysis to be at least in part magnetic oxide. The conditions of the experiment were such as are actually present in the case of rails: the rust which forms on the rails after a rain or during damp weather has rarely the time to become dry before the passage of a train converts it into magnetic oxide. For further proof, the scales on that surface of a rail which received the greatest pressure were removed by the aid of a brass wire brush and submitted to analysis. They were found to be composed of magnetic oxide mixed with a variable quantity of ferric oxide and apparently a small proportion of free iron. W. H. G.

CUTCH AND GAMBIER.—Henry Trimble (*Am. Jour. of Pharmacy*, **60**, 497). Read before American Pharmaceutical Association, September, 1888.

Six samples, three of cutch and three of gambier, were analyzed, with the following results:

	Cutch.			Gambier.		
Samples No.	1	2	3	4	5	6
Catechin, ...	2·80	1·70	10·70	12·64	7·76	19·76
Catechu-tannic acid, .	31·94	33·54	25·50	33·34	47·18	45·90
Total valuable constituents, ...	34·74	35·24	36·20	45·98	54·94	65·66
Mucilage, ...	27·40	29·01	20·50	10·13	15·20	16·05
Ash.	2·29	2·27	2·10	4·74	3·37	3·50
Moisture, ...	12·50	12·20	15·36	10·33	11·03	9·90
Coloring and other inert matter, ...	23·07	21·28	25·84	28·82	15·46	4·89
	100·00	100·00	100·00	100·00	100·00	100·00

The method of examination was to separate catechin, by agitating the aqueous solution with ether, then treat portions of samples with "hide powder," according to the method of Simnad and Weiss (Dingler's *Polyt. Jour.*, **260**, 564), which gave the catechu-tannic acid.

It has long been a statement in text-books that cutch and gambier are identical in chemical composition. It has, however, never been proven, and

I am convinced that it is entirely erroneous. In the above samples, no crystallized catechin could be obtained from samples 1 and 2, and only a small quantity from 3, while it readily crystallized from the aqueous solution of the ethereal extract of gambier. Both the physical appearance and the analysis indicate that there are important differences in the coloring matter of the two. This is further emphasized when we consider their respective commercial uses. The tanner selects gambier for his purpose because he wishes tanning material without color; the dyer prefers cutch because he wants coloring matter as well as tannin, the color in some cases being the more important of the two.

From the published accounts of the methods of preparing these two drugs, it is impossible to believe they could be chemically indentical.

Apart from their different botanical origin, the long-continued heating necessary to extract cutch from the hard heart-wood is so different from that required to exhaust the more porous twigs and leaves of the gambier, that the evaporation in the case of the cutch is carried directly to dryness, the decomposition products being such as to prevent the "setting" of the mass as it does in the case of the gambier.

In the latter the concentration of the liquor is stopped when it reaches the consistency of syrup, and the liquid by stirring and cooling "sets" on account of separation of catechin, becoming of such solidity that it can be cut into blocks, and further dried at such a low temperature that comparatively little change takes place. When gambier comes in cubes it precludes a kind of adulteration which is extensively carried on with cutch, namely, the admixture of small stones, pieces of earthenware and bricks.

Such adulteration is liable to be overlooked in selecting samples for analysis, and is best indicated when a large lot is powdered and portions of this analyzed.

Two samples of powdered cutch were examined, and yielded 14·01 and 18·20 per cent. of ash, which were made up of sand and crushed stones. These samples had been further reduced in value by the heat necessary to dry them previous to powdering, as is indicated by the following percentage results obtained by treatment with ether and alcohol.

Samples No.,	8	9
Soluble in ether,	0·90	8·75
Soluble in absolute alcohol,	9·93	17·50
Total valuable constituents,	10·83	26·25
Mucilage, etc.,	47·30	29·10
Ash,	14·01	18·20
Moisture,	14·10	7·30
Insoluble,	13·76	19·15
	100·00	100·00

Gambier in cubes could not be so adulterated, and it is so dry as to be readily powdered without previous heating to expel moisture. It is stated that gambier is adulterated by the addition of clay, but this admixture is

probably not more common than it is with cutch; in both it may be detected by the amount of residue left on burning. W.

THE ACTION OF MERCURY ON PLATINUM.—Crafts (*loc. cit.*).—Thin platinum foil is unattacked by cold mercury, but after long boiling in a flask sealed to prevent the admission of air, the foil is gradually corroded. The platinum is only partially dissolved by the mercury, the greater part of that which disappears separating in the form of a black powder, which is nearly all held in suspension. The surface of the mercury remains clean, but if a current of air be drawn through it, the platinum powder collects together, and if the mercury be then distilled, a very small residue of platinum is found.

W. H. G.

ON THE CAUSE OF METALLIC LUSTRE.—W. Spring (*Bul. Soc. Chim.*, **50**, 219). Dove was the first to attempt an investigation of the physical circumstances that are concerned in the production of metallic lustre. He had examined, by the aid of a stereoscope, two images of a pyramid, one being colored blue and the other yellow, expecting to find a relief image of a green color; he was, however, astonished to find that the mixture of colors gave a reflection like that of a polished metallic surface. Having repeated the experiment, using a black and a white image, he obtained the metallic gray of lead and tin. From these experiments, Dove concluded that metallic lustre is due to two reflections from superposed surfaces, and that the accommodation of the eye being different for each color, a perfect coincidence of the images of different colors was impossible. The lustre of metals would thus be caused by a reflection from the actual surface, and another from beneath the surface.

This explanation attributes a considerable degree of transparence to the metals, more indeed than seems consistent with fact. Brücke offered another theory, according to which the color of light reflected from bodies not possessing the metallic lustre should be independent of the local color; that is, the color of the reflecting body; while in the case of metals the color of the reflected light is that attributed to the substance, the incident light being white. Brücke also considered that a certain intensity of reflection was a necessary condition for metallic lustre, this intensity resulting from the opacity of the metals, and he mentions the phenomenon of total reflection as producing a perfect imitation of metallic lustre.

The theories of Dove and Brücke represent opposing views of the transparency of the metals: the one considers them as opaque, the other as transparent. The author endeavors to reconcile these views by a study of the nature of the surfaces of the solids he has obtained during his experiments on the compression of solids within polished steel cylinders. He finds that substances which in the form of powder are opaque, produce solids that have a metallic lustre, whatever the nature of the substance; while such substances as yield powders more or less transparent formed cylinders having *vitreous* surfaces, looking as if varnished. Between the vitreous lustre and the most perfect metallic lustre there are all the degrees that could be made between opaque and transparent substances, the greatest metallic lustre being devel-

oped when there is the greatest opacity. The metallic lustre then depends on the physical condition of the substance and not on its specific chemical nature. A metal which could exist in an allotropic form having a certain transparence would be capable of assuming a vitreous lustre. W. H. G.

THE WELDON-PECHINEY PROCESS FOR THE MANUFACTURE OF CHLORINE.—J. Dewar (*Jour. Soc. Chem. Ind.*, **6**, 775, through *Jour. Chem. Soc.*, **54**, 411). This process has been worked at Salindres in an experimental plant, designed to produce a ton of chlorine daily. The process consists (1) in dissolving magnesium oxide in hydrochloric acid; (2) making magnesium oxychloride; (3) crushing, breaking and sifting the oxychloride; (4) drying the oxychloride; (5) decomposing the oxychloride by heated air, magnesium oxide being left to again go through the first operation. The solution of magnesium chloride is evaporated so that it contains not more than six equivalents of water, and is then converted into oxychloride by mixture with one and a third equivalents of magnesium oxide. The mass becomes very hard and disengages much heat during solidification, although the operation lasts but about twenty minutes. The pieces are crushed into fragments about the size of a walnut, and these are freed from dust by passing through a rotating sieve. The oxychloride is then dried, and introduced into a special apparatus consisting of a series of furnaces having decomposing chambers heated by a movable regenerative burner. In the first stage of the decomposition there is a rapid evolution of steam which decomposes a part of the oxychloride forming hydrochloric acid that passes off with the water vapor. The resulting mixture of anhydrous magnesium chloride and magnesium oxide is decomposed by the oxygen of the air at the high temperature, only magnesium oxide remaining. The products are drawn from the furnace by an aspirator and passed through a hydrochloric acid condensing tower for the retention of the acid at first disengaged—and this is used in the first operation, together with more obtained by the decomposition of salt—while the mixture of air and chlorine passes on and is used for the manufacture of chlorate. W. H. G.

GIFTS TO THE LIBRARY OF THE FRANKLIN INSTITUTE.

Agricultural Experiment Station of the University of Wisconsin. Fifth Annual Report. From the Station.

American Academy of Music. Thirty-fifth Annual Report. From the Board of Directors.

American Ephemeris and Nautical Almanac for 1891. From the Bureau of Navigation.

American Philosophical Society. Transactions. Vol. 16. Part 2. From the Society.

American Society of Mechanical Engineers. Transactions. Vol. 9.
From the Society.

Armstrong, William, and others. Recent discussions on the abolition of patents for inventions. From Mr. R. A. Macfie.

Baker, Henry B. Recent Advances in State Medicine.
From the State Board of Health of Michigan.

Barus, Carl. Maxwell's Theory of the viscosity of solids and certain features of its physical verification. 1888. From the Author.

Boiler Explosions Act, 1882. Report of the President of the Board of Trade upon the working of the act, from June 30, 1886, to June 30, 1887.
From the Manchester Steam Users' Association.

Boston Society of Civil Engineers. Report of the Committee on Weights and Measures. From the Society.

Boye, Martin H. A Treatise on Pneumatics. Philadelphia, 1855. 8 vo.
From Dr. Isaac Norris.

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[*Proceedings of the Stated Meeting, held Wednesday, October 17, 1888.*]

HALL OF THE INSTITUTE, PHILADELPHIA, October 17, 1888.

Mr. JOS. M. WILSON, President, in the Chair.

Present, 213 members and thirty-six visitors.

Additions to membership reported, two.

The President, in conformity with a resolution of the Board of Managers, presented and read a carefully prepared statement of the financial condition of the INSTITUTE, which exhibited the fact that the current income was insufficient to meet the current expenses, and that the usefulness of the INSTITUTE is, and for years has been, seriously hindered by reason of insufficient means.